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Flax and its Possibilities in Australia.

*By A. M. Munro, M.A. (Oxon).**

The linen flax plant (*Linum usitatissimum*), of the variety used for fibre, consists of a single slender stem, growing to a height of about 3 feet, without branching. The small leaves appearing on the stalk are few in number and wither when the plant is ripe; the flowers are blue or white, and the seed (linseed) is carried in small capsules. So tough and strong is the stalk that it is almost impossible to break it with a steady pull, a characteristic due to the bundles of fibre being arranged concentrically round the core, extending for nearly the whole length of the stem, and constituting, when separated from the straw and suitably treated, the flax of commerce. Flax, under correct conditions of cultivation, grows very evenly, and an area of green flax is a beautiful sight, of billiard table appearance and smoothness.

Speaking generally, flax can be divided into two broad classes, linseed flax and fibre flax, the former a shorter branching plant, bearing a maximum quantity of the linseed which is used for oil making, cattle feed, and other purposes; the fibre flax has been developed by careful selection to yield a high percentage of straight, strong fibre. Linen flax, under the general name of "flax," should not be confused with the so-called New Zealand flax, a hard fibre of the hemp class, derived from a broad leaved plant (*Phormium tenax*) and of somewhat limited application.

Economic Importance of Flax.

The importance of flax may be gauged from the following figures:—The world has some seven million acres planted with fibre flax alone, although in some cases the seed is recovered also, producing each year nearly one million tons of fibre, worth about £90,000,000. For the sake of comparison it is interesting to note that the enormous cotton industry has an annual production of approximately eight million tons. Nevertheless, the production of flax ranks as one of the world's great industries. Supplies for Great Britain are obtained from Belgium, France, North Ireland, and the Baltic countries. At the same time,

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successful efforts are being made to establish flax-growing and fibre production in the British Empire, and, although the relatively small quantity of about 70,000 tons of fibre is imported into the United Kingdom for linen and cordage manufacture, it is of the highest quality and the latter industries are of the greatest national importance and value. The view has recently been put forward that, so far as vegetable fibres are concerned, raw material should be grown within the Empire under direct supervision. This is necessary not only for defence reasons, but because the highest quality can hardly be achieved in the finished products unless the growing of the raw materials is controlled.

The Flax Position in Australia.

Present Australian requirements of high-grade flax fibre are probably in the neighbourhood of 1,500 tons, valued at about £A150,000, and are likely to rise steeply in the near future as the Commonwealth increases both its rope and textile industries and possibly even enters the linen field.

With regard to the production of linseed the opportunity is also great—some 3,250,000 gallons of linseed oil are consumed in this country annually—provided that land values and labour costs are low and the yield of seed high.

Many attempts have been made at intervals during the past 50 years to establish the flax fibre industry in Australia, but it is only recently that they have met with success. Among the factors militating against earlier progress have been a lack of expert knowledge and information both with regard to growing flax and extracting the fibre, the employment of incorrect methods for separating the fibre from the straw, the absence of an assured market for the fibre, low world prices, unsuitable seed, attempts to grow a dual purpose variety both for seed and fibre, and finally the necessity in most cases for securing a quick return on invested capital. These disadvantages have now been removed. In one notable instance, flax is now grown by many farmers under contract with a manufacturing company who agree to purchase the crop at a guaranteed minimum price. Pedigree seed is supplied by the company, and in order to maintain the quality of the fibre, no other seed must be sown, while certain growing procedure and conditions must be adhered to. This seed, developed in the first instance by the Linen Industry Research Association in England and Ireland, under such names as Liral Crown and Liral Monarch, will yield considerably more high-grade fibre than will the ordinary commercial varieties. In this way the manufacturers are assured of a high-grade, uniform product, and the farmers, during a normal season, an adequate return for their land and labour. Recovery of the seed from the flax straw, and the separation and preparation of the fibre, are carried out under scientific conditions by the company which is then in a position either to use the fibre in its own factories or to export it. It has now been definitely proved that flax equal to any in the world can be economically produced in Australia, and, with the withdrawal of Russia from the export market and the probable continuance of high prices for many years to come, commercial success is practically assured. Research into methods of fibre extraction and treatment and also into many other manufacturing details connected with the flax industry is now being undertaken by

the Council for Scientific and Industrial Research, while, in Victoria, growing and farming questions are being handled by the Victorian Department of Agriculture. As in many other industries, lack of knowledge of the flax problem and of scientific method has hitherto delayed the development of this valuable Australian asset.

Flax from the Farmer's Viewpoint.

Speaking in a general way, flax can be grown in rotation with cereal crops or potatoes on good friable loamy soils. A rainfall of not less than 24 inches is desirable, with a good precipitation between the months of June and October. The land must be free from weeds, level, and preferably of a light nature overlying heavier moisture-retaining sub-soil. The best sowing rate has been found to be, in Victoria, 70 lb. of seed per acre. A five-year rotation is recommended in order to guard against the development of certain pests, such as flax wilt, rather than to spare the land, for, contrary to the common opinion, flax does not unduly exhaust the soil. For fibre production, the crop is ready for harvesting when about two-thirds of the stalk has reached an orange yellow colour and when the seed bolls or capsules are sufficiently ripe to yield the seed if crushed between the fingers. In Europe, flax is always pulled up by the roots, either by hand or with specially designed pulling machines, but it has been found in Australia that it is quite satisfactory to cut the crop with a reaper and binder provided that the machine is a close cutting one. The farmer can thus deal with his crop in the usual manner, and under reasonably favorable conditions he is assured of a yield of approximately two tons of flax straw per acre with a gross return of £10 per acre.

Separation of Flax Fibre.

After the reaped straw has been delivered to the mill, it is first of all de-seeded by a process known as "rippling," and is then packed in a double layer, with the sheaves of straw standing upright, into large concrete tanks, capable of holding 10 tons of straw and 30,000 gallons of water. In this tank the flax is soaked or steeped in warm water for a period of about seven days during which bacteria develop and a fermentation takes place, resulting in loosening of the bundles of fibre contained in the straw through chemical and bacterial attack on the cementing substances. This process is termed "retting" and the factory where it is carried out a "rettery." When the ret is complete, the straw is rinsed with fresh water and then removed and dried, either in a drying tunnel where the wet straw meets a current of warm dry air or by standing in bundles or "stooks" in the open air. When dry the retted straw is then crushed in a "breaker" or "crimper" and finally beaten by revolving drums in a "scutching" machine. In this way the woody portion of the straw or, as it is called, "shive," is separated from flax fibre which, after machine combing or hackling, is ready for the spinning mill.

Other methods of retting have been used in the past: dew retting, consisting in exposure of the straw to the dew, rain, and wind while laid out on the ground, river retting, and dam or pond retting. Until quite recently, the finest grades of linen flax were made at Courtrai in Belgium by retting in the river Lys, the so called "golden" river, a

name derived from the golden colour it imparted to the flax fibre rather than to the value of the product. To-day, river retting in the Courtrai district has been entirely replaced by warm water tank retting. It is interesting to note that, in 1937, Belgium exported fibre to the value of £3,000,000. Dew retting, as practised until recently in Victoria, was not only unsuitable on account of the climate but it undoubtedly greatly retarded development of the industry because of the uneven nature of the product it yielded.

Chemical retting, which would allow accurate control and greatly reduce retting time, features unobtainable in bacterial processes, may offer a solution to the problem of still more profitable fibre extraction; the Council is accordingly concentrating its research in this direction. Fibre may also be extracted from the flax straw by purely mechanical means, the product being known as decorticated or natural flax, and indications point to an expanding market for this type of material.

Properties and Uses of Flax.

In its physical properties flax fibre is unique. It has, for example, great strength combined with silky feel and glossy appearance. Moreover, it can be spun into yarns of extraordinary fineness, some of the linen varieties running to no less than 10 miles in length to the pound avoirdupois. In addition, flax shows great resistance both to moisture, weathering, and washing conditions, and to abrasive wear; a linen sheet or tablecloth, for example, wears many years. It is also a good conductor of heat, a property which explains the cold feel of linen sheets or other fabrics. In addition to linen, flax is used for the manufacture of sewing thread, where strength and a very even diameter are required. It is also used for tarpaulins and canvas, blind cords, string, binder twine, fire hose, fishing lines and nets, and in all kinds of cordage and ropes where special strength and weather and abrasion resisting qualities are required. Obviously, it is a defence requirement and for this reason alone, as already pointed out, flax-growing should be carried out within the Empire.

Conclusion.

Flax is one of the major vegetable fibres of commerce, unique in its properties and of great monetary value. For some time to come the world market for flax will, on account of the tendency for nations to become self sufficient, be under-supplied, and an opportunity has arisen for profitable production within the Empire. Contributory to this, Australia has commenced production in a small way; at present some 2,000 acres are under flax, but in a modern and scientific manner, and there is good reason to believe that this new industry will in the near future become one of importance to this country.

The Need for a Legume in Northern Queensland.

*By J. F. Miles, B.Sc.Agr.**

The high rainfall tropical areas running up the east coast of Queensland are already exploited to a considerable extent in the production of some tropical products, principally sugar, whilst maize is grown upon the plateau regions of the hinterland; this production is based on the better class soils.

No doubt on some of these soils it would also be possible to grow other tropical crops such as rubber, copra, tea, &c., but this agricultural exploitation would find serious limits in the meeting of competition under world parity from countries where successful development has been attended with low production costs and much scientific research into particular climatological and soil adaptations. Further, there exists in these areas a considerable proportion of leached soils (podsols) of comparatively low fertility which would be comparatively costly to exploit for general agricultural products.

If then the prospects for the development of a more diverse tropical agriculture in Queensland are not particularly attractive, is there any other way in which these areas might be exploited? Fortunately for Australia there is the alternative possibility of intensively developing the grazing potentialities of this portion of the Continent and marketing plant protein in the form of animal products. But animals thrive best on a protein-rich pasture, and this in turn means a pasture containing legumes which are richer in protein than grasses and also carry into the soil the all-important nitrogen. Unfortunately, Queensland has long been hampered by the lack of a legume that will grow satisfactorily in her northern areas—and Queensland has not been alone, of course, in that disability. It is, therefore, not surprising to find that much scientific investigation has centred round the problem of finding a legume that will grow under tropical conditions. Through the Plant Introduction Section of its Division of Plant Industry, the Council for Scientific and Industrial Research has been working in this field for the last few years.

Of late years the dairying industry has been successfully extended into Queensland tropical areas, and there has also been a considerable production of fat stock for export as "chillers." This latter activity has received an impetus from the elucidation of the animal health problems involved in the transference of cattle from inland areas to the coast without the danger of heavy losses by death following tick-fevers and pleuro-pneumonia. Furthermore, the success which attended the initial experimental shipments of chilled beef to the United Kingdom commencing in 1932-33, together with the subsequent allocation of quotas in that market, gave an added stimulus, and by 1936-37 the shipments from Queensland approximated £600,000 in value. The possibilities of an increasing share in this trade of the United Kingdom market can be gauged from the total British imports of chilled beef in that year, approximating £17,000,000 in value—and more particularly if the policy of imperial preference remains within the sphere of practical politics.

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Other tropical countries within the British Commonwealth are interested in the production of "chillers," and much research work is being performed in parts of British Africa upon the economic production of a 600-lb. carcass within a 3 to 4 year growth period.

In Rhodesia, e.g., on the Rhodes Matopo Estates, beef animals have been grazed during summer months upon the natural pastures. With the advance of winter, and during periods of nutritional stress, supplementary feeding with protein concentrates and natural and leguminous hays was undertaken. This feeding, supplementary to the natural pastures, was at various leve's and in accordance with the requirements of a pre-determined theoretical growth curve—and so in this manner a 600-lb. carcass has been produced for marketing within a growth period of $1\frac{1}{2}$ years, $2\frac{1}{2}$ years, $3\frac{1}{2}$ years, and 5 years, the most economical age (in terms of cost per 100 lb. of beef) being $3\frac{1}{2}$ years. It must be noted that there is an additional economy with this early marketing in the freeing of the pastures for further production.

At the University of Pretoria, the Grassland Research Committee of the Faculty of Agriculture has been testing the productive capacity of Rhodes grass in terms of beef, interpreting the results in live-weight gains (and ultimately in quality of beef produced). They reported that, during the 1936-37 season, 7 Aberdeen Angus steers were grazed in rotation upon 7 one-acre camps of Rhodes grass in "such a manner as to ensure the optimum use of the herbage and at the same time secure a suitable hay-crop." This hay was later fed to the cattle. "The 7 acres of Rhodes grass provided grazing and hay sufficient for 7 steers for 221 days and the nutrient supplied was such as to allow a gain in weight, during this period, of 222 lb. per steer." Further work upon feeding Rhodes grass hay with protein concentrates then followed.

In Tanganyika, M. A. French has worked out the digestibility coefficients of most African feeding stuffs.

In Queensland, we too have yet to solve this problem of economically producing in large quantities the chiller carcass as required by the British consumer. To date, valuable pioneering experimental work has been performed in North Queensland using Para, Molasses, and Guinea grass pastures with cattle from the Gulf country, on the property of Mr. Brice Henry, at Tully, in which experiments the Queensland State Department of Agriculture and Stock has taken an active interest.

The furtherance of the chilled beef export trade requires a continuity of production throughout the year rather than the peak output at present experienced over a few months. Upon present natural pastures, the beef animal is at the mercy of the climate, and the weaned animal has to face each year periods of low, alternating with high, feeding. To ease this position the supply of plant protein must be equalised throughout the year.

One method of attack is the introduction of grasses with a high productivity over a long growing season, and seeded in permanent pastures. Such pastures, with a suitable leguminous component, would be ideal for fattening beef cattle, and should be successful in the more favourable localities.

On the other hand, in North Queensland there are thousands of acres of natural pastures distributed through partially improved open forest country which do not lend themselves to such a treatment but

which are carrying large herds of cattle. It is even more important that a legume be found for these pastures as a source of soil nitrates for the grasses and as a constituent rich in protein, calcium, and phosphorus for the grazing animal. Top-dressing of the legume with lime and superphosphate* would possibly be efficacious.

The pasture-legume problem of sub-tropical and tropical Australia has been reviewed by W. Hartley (*Herbage Reviews,* Vol. III., No. 1), who stressed the need for searching for new species to supplement the existing resources. Two years earlier William Davies, in his report upon "The Grasslands of Australia" (C.S.I.R. Pamph. 39), referred to the need for an efficient pasture legume—"a perennial for preference, but failing that, a self-regenerating annual."

The self-regenerating annual type of legume, such as subterranean clover, has been of inestimable value in the more temperate climates where the evaporation factor is less intense in its effects, and as a consequence the lengthened period of influential rainfall allows the development of this group of relatively shallow-rooting legumes. Unfortunately, legumes of this type are not suitable for the tropics, for rains in tropical areas fall in the summer and are often very heavy. Where the rains are of long duration and intensity, the leaching factor must be considerable. In areas of lower rainfall, the high evaporation, even following heavy rains of short duration, gives a consequent rapid drying of the surface soil, and this in turn must favour the development of deep-rooting perennial pasture plants.

The areas of Australia in which the establishment of exotic plants is, or appears to be practicable have been treated by A. McTaggart in this Journal (Vol. XII., No. 2), whilst J. A. Prescott has described the climate of tropical Australia in relation to possible agricultural occupation (*Trans. Roy. Soc. South Aust.* **62**: (2) 1938). These generalised surveys have employed climatic constants and are valuable indications of areas of potential developmental value. But there is still needed a detailed climatological survey of the sub-coastal and coastal areas of the north-eastern portion of the continent, with particular reference to the rate and depth of penetration and availability throughout the year at various levels, of rainfall absorbed by the various soil types, as upon this is so closely dependent the type of pasture cover.

In the meantime, the efforts of the plant introducer must be directed towards obtaining highly-productive, palatable, and persistent grasses of long-growing season for permanent seeded pastures in the better rainfall areas, and towards searching for a selection of suitable legumes which can be used in these and less favoured areas. This latter is of particular importance when consideration is given to the well-known effects of nitrates in reducing transpiration, and effecting a more efficient utilisation of moisture by the plant.

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* The necessity for applications of lime and nitrogenous and phosphatic fertilizers in varying amounts upon numerous areas in coastal Queensland producing sugar-cane (which after all is a Gramineous species), has been demonstrated by the Bureau of Sugar Experimental Stations in its comprehensive farm fertility and other trials. A deficiency of phosphorus in the soil and herbage has been adduced as the cause of outbreaks of peg-leg of cattle in North Queensland, and there are many properties where phosphatic licks and meals are fed in order to avoid any possible deficiencies of mineral constituents of the diet limiting the rate of growth.

Various pasture species from Africa, South America, and India have been under observation at the Fitzroyvale Plant Introduction Station of the Division of Plant Industry since the 1936-37 season, and a selection of grasses has now been seeded into grazing plots in combination with a leguminous component, in search for species suitable for permanent seeded pastures.

Preliminary tests, over the last three years, embracing a number of legumes, have revealed the promising growth of *Stylosanthes guyannensis* Sw. (C.P.I. 5630 and 6058)—vernacular name " trifolio "—from Brazil. There is also a less-productive variety, *S. guyannensis* Sw. var. *subviscosus* (C.P.I. 5631)—vernacular name in South America " meladinho ". The species has previously been reported upon by A. McTaggart in this Journal (Vol. X., No. 3). Under the limited climatic testing to which it has been possible to subject this legume, it has been observed that it maintains growth during dry-periods, is deep-rooting (an aerial portion of 6″ in height possesses a primary root 18″ in length), and retains its leaf throughout the year until near the completion of seed production. Following this, with the first replenishment of soil moisture with early storm rains of summer, active growth is immediately in evidence. Analyses have indicated that mature plants possess a protein content of approximately 16 per cent. The species has been grazed by cattle in experimental plots, and has shown a tendency to establish itself in natural pastures and compete successfully with bunch spear grass (*Heteropogon contortus*). As a consequence, experiments are now being planned to test the possibilities of establishing this perennial legume in natural pastures, top-dressing with superphosphate, with and without cultivation.

Arachis prostrata (C.P.I. 6930) is a perennial peanut which has a wide distribution naturally throughout tropical and sub-tropical South America. (There are several species within this genus occurring naturally in that continent, and efforts are being made to introduce these for testing in coastal Queensland.) It is a short-lived perennial, decumbent, and freely rooting at the nodes, giving a leafy growth up to 6″ in height, and rich in protein. The fruit is buried about 2″ below ground level. This species is being tested as a leguminous component of permanent seeded pastures in the hope that it may prove the equivalent of subterranean clover under a high summer rainfall.

Numerous varieties of perennial and annual " Lespedezas " have been introduced. The perennials, *L. sericea, L. juncea,* and *L. daurica* have not been outstandingly productive at Fitzroyvale. Strains of the annuals *L. striata* and *L. stipulacea* have been tested also, but growth has been very limited during periods of high temperature. They may have a place in temporary pastures in rotations in sub-tropical areas.

Meibomia discolor (C.P.I. 5815) is a perennial legume which is also under test. It is reported to be the best known legume of cattle pastures on good soils in Brazil. It becomes shrubby when not defoliated. It has been introduced into Colombia from Brazil and has been noted as being readily eaten both green and as hay by cattle.

This raises a further point as to the value of endeavouring to obtain a legume which could ultimately be a tropical substitute for lucerne. The inland areas of North Queensland have experienced severe fodder shortages in many years and the years 1888, 1902, 1915, 1919, 1923, and 1926 may be mentioned. Many animals obtained through careful breeding over long periods have perished during these

droughts, and enormous sums have been expended in relief methods such as agistment, droving and transport over long distances, or hand-feeding. Lucerne hay and maize have been extensively used in the drought feeding of stock, but the landed cost upon the stations is often prohibitive during a protracted drought. A leguminous substitute for lucerne to be grown on the north tropical coast could well be sought for drawing upon by these inland areas during dry periods.

Cajanus indicus (C.P.I. 6053-54-55)—Pigeon Pea—is a leguminous shrub which has attained a height of 8 feet in test rows at Fitzroyvale. Flowering during the autumn and winter, it bears a heavy crop of green pods during the spring months, whilst being rich in foliage. In the Hawaiian Islands, over 4,000 acres are reported as being under crop to this legume, as supplementary pasture for maintaining growth of fattening cattle when natural pastures decline in productivity.

Extensive testing of varieties of soy-beans is being instituted in an endeavour to obtain information upon the adaptation and productivity in Central Queensland of this valuable, leguminous protein-producer. In the United States of America, 3,659,000 acres of the soy-bean were harvested for hay alone in 1937. The hay of the annual soy-bean compares quite well with that of perennial lucerne.

William Davies* has raised the question as to whether it is better to concentrate upon temperate plants of recognized value and to find the means of building them into swards under tropical conditions. In this connection it is interesting to observe that Dwalganup and Springhurst strains of subterranean clover (*Trifolium subterraneum*) have regenerated successfuly at Fitzroyvale in the absence of a plant cover upon the surface soil, but it is considered that a high percentage ground cover of summer-growing grasses would preclude successful germination of this species under natural conditions of an open permanent pasture. Regeneration has been observed during the month of March.

Hedysarum coronarium (C.P.I. No. 5531)—Sulla—has made excellent growth at Fitzroyvale during the months of July, August, and September (when flowering occurs). Summer growth is very limited with this Mediterranean legume, but the productivity during these spring months is a feature of considerable interest. Breakwell reported that at trials at Glen Innes Experiment Farm it made fair winter growth and good growth in spring and early summer, to flower profusely throughout November, but set no seed. Seed has been set freely at Fitzroyvale. It is possible that this legume may have a place in pasture mixtures in sub-tropical areas where semi-permanent leys of 2-3 years duration are fitted into rotations.

Meantime, it should be clearly understood by all who may be interested in these introductions and trials, that nothing final can as yet be concluded regarding them. They are merely promising—in certain cases distinctly so. Further and diversified trials in the next few years will eventually determine their permanent value or otherwise.

Whilst the testing of productive grasses of long growing season, for use in permanent pasture swards in the better rainfall areas, for the fattening of "chillers" and for dairy pastures is of considerable importance, nevertheless the obtaining of a suitable legume for establishment throughout the natural pastures of North Queensland should be the major plant introduction and agrostological problem in any programme of pasture research for this area.

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* Coun. Sci. Ind. Res. (Aust.), Pamphlet 39, p. 28, 1933.

The Preservative Treatment of Fire-Killed Mountain Ash (*E. regnans*) and Alpine Ash (*E. gigantea*).

By J. E. Cummins, B.Sc., M.S. and R. F. Turnbull, B.E.†*

Summary.

Details are given of the causes of deterioration of fire-killed timber from a study of two areas containing mountain ash killed in the 1926 and 1932 fires, and of the conditions favouring the development of degrade from physical causes, pin-hole borers, and decay. Recommendations are made for the preservative treatment of salvage-felled timber, stored under varying conditions.

1. Introduction.

The salvage of fire-killed timber made necessary by the fires which devastated forests of mountain ash and alpine ash in Victoria in January, 1939, is a problem of considerable magnitude. Some 900,000,000 super feet of logs, it is estimated, are recoverable from the burnt-over country. This is equivalent to approximately ten times the normal annual cut of the affected species prior to the fires.

If utilization of this quantity is to be accomplished, rapid re-establishment of the industry will be necessary, and steps must be taken to protect the burnt timber from deterioration.

It is evident that no one method of log protection can be used and that various methods will be necessary even on the one restricted logging area. The following notes are made as the result of preliminary investigations on mountain ash in the Erica and Neerim South districts. It should be emphasized that the recommendations made and the observations recorded are based on a relatively small amount of data. The lack of fundamental information, for example, on the types of borers likely to attack the timber, and their life histories, or the rate of development of the different types of rot in standing trees and logs, has necessitated the drawing of inferences which are only as sound as the data available. They are, however, the best recommendations that can be made at this juncture, and are advanced for the consideration of sawmillers operating in all mountain ash and alpine ash forests. As the salvage plan will extend over a period of years, it is probable that modifications will subsequently be made to some at least of the recommendations as a result of practical experience and further investigations.

2. Causes of Degrade.

From observations and conversion studies made in the Erica and Neerim South districts, it appears that, in the case of the 1926 and 1932 salvage felled mountain ash, pin-hole borers, physical degrade such as checks, and decay are of importance in the order named. Termites were also a factor in the 1926 salvage felled mountain ash

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in the Neerim district. Standing 1926 and 1932 fire-killed trees are more seriously affected by checking, on account of more severe exposure to drying conditions. Borers are about equal to checks in their degrading effect. Decay may be of definite significance, but, in the case of 1926 fire-killed standing trees, there is evidence to indicate that in a period of thirteen years decay extension from areas existing at the time of the fire was not serious.

3. Conditions Favouring the Development of Degrade.

(*a*) *Borers.*—In the main, it appears at the moment that at least two distinct types of pin-hole borers are likely to cause degrade in salvaged timber.

Platypodid borers—probably *Crossotarsus omnivorous*—have been seen attacking fire-killed mountain ash, the beetles penetrating the bark and laying their eggs at a depth of several inches into the tree. In the case of this borer, *both beetles and larvae are capable of boring.* No data are available on its detailed habits. In the case of *C. grevilleae*, a North Queensland borer, it appears that the attack so initiated by one infestation of insects continues developing in the log for a period of probably only two years at most. In the case of trees gradually shedding their bark, there may be several distinct periods of infestation. Ageing of the tree, probably partial drying of the surface, acting either as a physical factor or as the result of a loss of chemotropic attraction, deters and appears eventually to prevent attack completely.* No stages of *C. omnivorous* were seen during the conversion of the test timber or in an examination of material therefrom. From inference, then, the *C. omnivorous* may only attack fire-killed logs for a limited period and the use of preservative sprays may be of value, especially in areas where the presence of *C. omnivorous* is recorded. It is possible that *C. omnivorous* may initiate attack in barked logs, but it is possible that barking may reduce the extent of attack. *C. grevilleae* infestations only occur in warm weather, over 80°F., and the top lateral surface of the log is preferred. Logs left under heavy canopy are not subject to attack. Observations in the Erica district and discussions with the local forest officers and sawmillers indicated that what is apparently Platypodid attack was most serious in exposed situations and away from areas where the re-growth and scrub cover was dense. Here again, a temperature effect is indicated, which is of significance in the question of dumps. The period of maximum infestation by *C. omnivorous* is probably the latter part of the summer from February to March, but this point definitely needs confirming. It is also not certain whether more than one brood develops in a year.

The second type of borer causing damage to 1932 salvage felled and standing fire-killed timber in the Erica district is a Lymexylonid. This type differs very materially in its life history from the Platypodid type. The beetle cannot penetrate the bark or wood and it lays its eggs on exposed wood surfaces, preferring those which have been weathered somewhat. *Only the larvae bore in the wood* and the life cycle from the egg to the beetle stage is probably at least two years. Infestation and re-infestation may continue over a long period of time. Although

* Smith, J. Harold.—The Pin-hole Borer of North Queensland Cabinet Woods. Queensland Department of Agriculture and Stock, Bull. 12, 1935.

much less evidence is available, it appears again that good shade is inimical to infestation. In the 1932 fire salvage material converted at Ezard's No. 2 mill, live Lymexylonid larvae of two distinct species were present in some of the logs and had caused extensive damage. Live larvae were also present in the 1932 standing trees and again had caused considerable damage. It appears that the beetles emerge from December to February, during which months infestation is possible. Damage from these borers will not occur until the bark is shed. It is doubtful if much damage will occur in the summer of 1939-40, but the intensity of attack can be expected to materially increase the following year and in subsequent years. In the Erica district, the greater proportion of the borer damage in fire-killed trees and salvage felled logs is due to the Lymexylonids. This same condition probably holds in other districts, and protection from this group of borers is of major consideration.

(*b*) *Physical Degrade.*—Physical degrade as exemplified by checks and splits caused by drying of the tree or log is dependent upon the degree of exposure to drying conditions. Drying from the end grain is very much faster than from the side, and drying stresses at the ends can be expected to show up first and to be of serious consequence as a degrading factor unless suitable precautions are taken. It was noted in the Erica district that standing trees were more severely checked than salvage felled logs. Again, salvage felled logs, provided with good vegetative cover, were less checked than those more exposed. In general, to prevent physical deterioration due to drying stresses, logs should be protected as much as possible from direct exposure to the sun and wind. Wherever possible salvage felled material or dry dumps should not be left or placed on exposed knolls or ridges or in general exposed to a northerly or westerly aspect unless good vegetative cover can be expected soon after felling. It is obvious that physical injury caused by felling cannot be avoided. Such injury, however, should be reduced to a minimum, as coatings cannot be applied to felling shakes and shatter, and these exposed surfaces act as centres for the development of subsequent seasoning defects.

(*c*) *Decay and Stain.*—Decay and stain of fungal origin need to be considered separately from stain due to chemical or other causes. Fungal decay and stain both require suitable conditions of moisture and warmth, and their development in salvage felled material, dry dumps, &c., appears to be inevitable. The resultant degrade, however, will only be small and in no way comparable with that from borers and mechanical degrade. In the case of decay, it appears that after a period of some years the sapwood will decay to a greater or lesser degree from external infestation. Observations at Erica showed a varying degree of sapwood decay from sound to completely rotted. In the 1932 salvage felled material, there was no serious extension of the sapwood decay to the immediately underlying truewood. Where logs contain rot at the time of felling it is considered they should be utilized as soon as possible and not included in dumps. If any sorting can be made, rot-affected logs for storage should be left as salvage felled material or hauled to extraction lines only. Chemical stains and stains from weathering are not considered to be of serious consequence. These are more apparent on the surface of cracks, and any means adopted to reduce cracks will automatically reduce this type of stain. In the case

of the exposed ends of logs, suitable end coats will give protection against both fungal and chemical stains. In regard particularly to rot and fungal stains, the presence of borers markedly increases the amount and extent of these in the truewood. Very small borer holes often show considerable darkening of the edges and longitudinal extension of stain from the galleries. Prevention of borer attack will prevent the development of the fungal stain associated with them and reduce the extension of rot.

4. Preservative Methods for the Salvaging of Fire-Killed Timber, Recommendations and Estimated Costs.

For worthwhile results, preservative treatment must be applied before deterioration begins. It will not undo damage that has already taken place.

(*a*) *Standing Trees.*—It appears that standing fire-killed trees should be cut within a period of about two years subsequent to January, 1939. It is expected that the killed trees will have shed their bark within one year, and thereafter degrade from physical causes (checking) and borers will be more rapid. Beyond two years, utilization will probably be seriously affected, but an economic recovery may be obtainable from selected trees up to a period of about four years.

No method for the treatment of standing trees can be advocated.

(*b*) *Salvage felled Trees.*—In the past, no treatment has been given to salvage felled timber. As indicated previously, salvage felled logs should be as far as possible left in shaded and non-exposed sites. It is recommended in all cases of salvage felling that immediately after felling the sloven be sawn off and that an end coating be applied immediately. The end coating recommended consists of a mixture of 8 parts of petrolatum to 9 parts of creosote oil by weight, or 12 gallons of petrolatum to 13 gallons of creosote. This mixture can be prepared by merely adding warmed creosote to the melted petroleum jelly and then allowing the whole to cool. The cold mixture is of a thick consistency and can be readily brushed on to the ends of the logs. Tests have shown that it adheres to wet surfaces and no difficulty should be experienced from its use. It is applied to give a layer about 1-32 inch thick at the rate of 1 lb. of mixture to 7 square feet of surface. This end coating should be fairly permanent and will materially reduce the development of end checks or cracks. The creosote oil present will act as a borer deterrent in the end of the logs and also prevent the ingress of stain and decay. With an effective end coating, end degrade and resultant long butting as experienced in previous salvage felling will be largely eliminated. The average cost of end coating, excluding labour and averaged over logs from 18 inches to 42 inches centre diameter, is 0.16 pence per 100 super feet in the log. Labour cost of application will be very small, and if done by the fellers would not affect their daily tally. The cost of materials in Melbourne is estimated at 2d. per lb. of mixture. A figure of 3d. per lb. of mixture is used in arriving at the detailed costs given in Table 1, and in subsequent estimates for end coatings.

It is understood that no provision has been made in the salvage plan for any treatment of salvage felled material, but the inclusion of end coatings is definitely advocated. The cost of removing the sloven will, of course, add to the cost and should be allowed for at probably

an average of about $\frac{1}{2}$d. per 100 super feet. On account of general inaccessibility and the condition of the forest floor after felling, it appears impracticable to treat the bole effectively.

(*c*) *Logs Hauled to Extraction Lines.*—As with salvage felled material, these should be protected as much as possible by keeping extraction lines away from ridges and exposed areas. Removal of sloven from the butt and the application of creosote-petrolatum mixture to both ends is strongly advocated. The average cost of this is estimated at 0.22 pence per 100 super feet in the log.

It is also recommended that where possible, especially if field evidence indicates the possibility of borer infestation, all logs hauled to extraction lines be barked and the bole given a spray treatment with creosote oil. It is realized that the area in contact with the ground and right adjacent to it cannot be sprayed. This portion in direct contact with the ground is not susceptible to borer infestation, and attack in adjacent underlying areas can be expected to be very slight indeed. Details of cost of spraying are given in Table 2. The average cost is about 3.37 pence per 100 super feet in the round. Estimating barking at 1.5 pence per 100 super feet and end coating at 0.22 pence, the total cost of treatment is about 5.1 pence per 100 super feet.

End coating should be carried out immediately after felling and cross-cutting of log lengths. When hauled to extraction lines, the end coating may be disturbed in places and should be patched up just prior to spraying, the latter being carried out when the log is hauled into place. The existing fire knapsack sprays should be suitable for creosote spraying, although it may be necessary to use a different type of spray nozzle which can only be determined after trial.

Logs treated as above should last materially longer than salvage felled material, and it is considered that the cost of such treatment would be fully justified in reducing degrade.

(*d*) *Dry Log Dumps.*—These may be of two types, covered and uncovered.

In the case of uncovered dumps, it is recommended that all logs be end coated at the time of felling and cutting, and when hauled to the dumps the end coating patched up where necessary. The logs should be completely barked and, after haulage to the dump, sprayed with creosote oil. The total cost of this treatment only is estimated at about 5.1 pence per 100 super feet. The building of dry dumps reduces the possibility of effective shading, and the exposed logs will thus be liable to mechanical degrade. The logs inside the dump will be materially protected from such degrade. The exposed logs will, however, be a large proportion of the whole, and, from the physical degrade stand-point, uncovered dry dumps are not advocated. Again, if dry dumps are used and creosote spray application not made to the barked bole, the incidence of borer infestation is expected to be high. Logs should be barked and hauled to the dumps as soon as possible after felling. This point is of greater significance during the summer months when borer infestation is likely to occur, and the hauling should be organized to have logs at dumps within 24 hours of felling.

TABLE 1.—END COATING OF SALVAGE FELLED TIMBER.

(Calculated on log length of 50 ft. and butt only coated.)

Average Diameter.	Super Feet. (Hoppus).	Area of Butt. (sq. ft.)	Calculated Cost of End Coating.*	
			Per Log. (pence)	Per 100 Sup. ft. (pence)
1 ft. 6 in.	817	3·1	1·33	0·16
1 ft. 9 in.	1134	4·8	2·06	0·18
2 ft. 0 in.	1504	6·0	2·57	0·17
2 ft. 3 in.	1881	7·2	3·09	0·16
2 ft. 6 in.	2350	8·7	3·73	0·16
2 ft. 9 in.	2763	9·6	4·12	0·15
3 ft. 0 in.	3325	12·5	5·36	0·16
3 ft. 3 in.	3876	14·0	6·0	0·16
3 ft. 6 in.	4537	17·5	7·5	0·17
			Average ..	0·16

* No labour cost for application included. (Cost of material estimated at 3d. per lb. and spread of 7 sq. ft. per lb.).

TABLE 2.—CREOSOTE SPRAY TREATMENT OF BARKED LOGS.

Average Diameter.	Super ft. (Hoppus).	Area of Bole under Bark.	Cost of Creosote per Log for one Spraying.*	Cost of Creosote per 100 Sup. ft.	Cost of Spraying Labour at 10 min. per 100 sq. ft. and Labour at 2s. per Hour.†	Cost of Spraying Labour per 100 Sup. ft.	Total Cost Creosote Spraying per 100 Sup. ft.
		sq. ft.	pence.	pence.	pence.	pence.	pence.
1 ft. 6 in. ..	817	235	33·8	4·14	9·42	1·15	5·29
1 ft. 9 in. ..	1134	275	39·7	3·50	11·0	0·97	4·47
2 ft. 0 in. ..	1504	315	45·4	3·02	12·6	0·84	3·86
2 ft. 3 in. ..	1881	355	51·1	2·72	14·4	0·77	3·49
2 ft. 6 in. ..	2350	395	56·8	2·42	15·8	0·67	3·09
2 ft. 9 in. ..	2763	430	61·8	2·24	17·2	0·62	2·86
3 ft. 0 in. ..	3325	476	67·6	2·03	18·8	0·57	2·60
3 ft. 3 in. ..	3876	510	73·5	1·90	20·4	0·53	2·43
3 ft. 6 in. ..	4537	550	79·	1·74	22·0	0·49	2·23
						Average	3·37

* Creosote estimated at 1s. 6d. per gallon on site and spread of 125 sq. ft. per gallon.

† Time estimated includes moving time from log to log.

In the case of covered dumps, the following is recommended:—Logs should be end coated immediately after felling and cross-cutting, and hauled to dumps as soon as possible (see above). At the dump, end coatings should be patched up where injured by hauling, &c. It is not necessary to bark the logs. After completion of the dump the whole is covered with a continuous cover of 18-oz. hessian. When the cover is erected, it should be sprayed with creosote oil. A creosote-sprayed hessian covering should adequately protect the logs from further infestation by borers. The hessian coating, in the summer months, will also act as a shade and reduce physical degrade. The presence of bark on the logs will also materially assist this. The hessian covering should be left on the dumps from late November to the end of March in each season. It can then be safely removed in so far as borer infestation is concerned, and thus protected from rain and winter storms. Details of the cost of such covers and the treatment of the logs are given in Table 3. It will be seen that, except for the smallest dump shown, hessian-covered dumps are cheaper per 100 super feet than uncovered treated dumps discussed above.

It is probable in both types of dumps that borers will be present in some of the logs at the time of erection. Elimination of these is difficult. It is suggested that during the first summer after erection, crystals of paradichlorbenzene be sprinkled over the top of the dump at the rate of 1 lb. of chemical per 5,000 super feet of timber. With the chemical at 1s. 6d. per lb. at the site, this will add, including labour, a charge of about 0.4 pence per 100 super feet to the cost per 100 super feet given in Table 3. The total cost of storing in covered dumps, therefore, will range from 3.14 pence to 5.84 pence per 100 super feet, depending upon the size of the dump. As re-infestation of logs in a covered dump comes from borers present in the logs at the time of erection of the dump, it is expected that this will occur chiefly towards the top and outside edges, where the effectiveness of the chemical added should be greatest. The creosote-impregnated hessian will prevent beetles reaching the logs in the dump, the hessian mechanically preventing Lymexylonid beetles, and the creosote assisting as a repellent, this latter aspect being more important in the case of Platypodids.

The use of hessian-covered dumps as outlined above is recommended in preference to uncovered dry dumps and the cost is not unduly high.

(*e*) *Wet Dumps.*—The complete submersion of logs under water will preserve them indefinitely from degrade. Experience in the United States of America has indicated that where complete submersion is not possible, then a degree of protection is obtained by keeping the logs under a continuous water spray.* Enough water must be used to keep the dump enveloped in a light mist; otherwise drying will take place from surfaces not directly exposed to the action of the sprays. It is also considered advisable to arrange the sprays so that both ends of each log are exposed to their direct action and so that the surface area is swept by intersecting sprays which would ensure each part still being watered if individual sprays become blocked. The rotary type sprays would be suitable for the general surface and a fixed directional

* Pertinent Facts on Salvage of New England Timber. United States Department of Agriculture, Mimeo. 1938.

TABLE 3.—COST OF END COATING LOGS IN DUMPS AND PROTECTING WITH HESSIAN.

Basis: Logs 50 ft. in length.

Height of Dump.	Width of Dump.	Log Sup. ft. (Hoppus).	Area of Log Ends.	Cost of End Coating both Ends per 100 Sup. ft. (1)	Cost of Creosote Spraying per 100 Sup. ft. (2)	Area of Hessian to Cover Dump.	Total Cost of Hessian for Covering. (3)	Cost of Creosote for Hessian. (4)	Cost of Spraying Hessian. (5)	Cost of Fixing Hessian on Dump. (6)	Total Cost of Hessian Protection. (7)	Unit Cost of Hessian Protection per 100 Sup. ft. (7)
feet	feet		sq. ft.	pence	pence	sq. ft.	shillings	shillings	shillings	shillings	shillings	pence
10	25	58,500	250	0·22	3·37	2,750	115	77	5	44	265	5·44
10	50	117,000	500	,,	,,	4,500	188	125	8	75	436	4·47
10	100	234,000	1,000	,,	,,	8,000	333	223	13	133	772	3·96
15	25	87,750	375	,,	,,	3,500	146	97	6	60	340	4·65
15	50	175,500	750	,,	,,	5,500	229	153	9	88	527	3·61
15	100	351,000	1,500	,,	,,	9,500	396	265	16	154	914	3·12
20	25	117,000	500	,,	,,	4,250	177	118	7	71	410	4·21
20	50	234,000	1,000	,,	,,	6,500	271	181	11	128	650	3·33
20	100	468,000	2,000	,,	,,	11,000	458	306	18	188	1067	2·74

1. Cost of materials only as for Table 1
2. For details, see Table 2. Average size log taken as basis.
3. 20 per cent. added to allow for overlap and irregularity. Cost of hessian based on 7½d. per yd., 72 inches wide.
4. Creosote estimated at 1s. 6d. per gallon at dump and spread of 0.18 lb. per sq. ft. which allows for three separate treatments.
5. Spraying cost estimated at 5 man minutes per 100 sq. ft.
6. Fixing includes sewing of seams (45 ft. per man hour, seams longitudinal on top and sides and vertical on ends), also placing on and removal from stack for six times. Placing estimated at 2·5 man minutes per 100 sq. ft. of hessian per time and removal at 1.5 man minutes per time.
7. Total cost includes an additional 10 per cent. on all charges to cover the possibility of damage to hessian during covering, etc.

spray for the ends. At current prices, sprays for a dump 100 feet by 100 feet would cost approximately £30. Pressures up to 40 lb. per square inch should be provided.

The main expense with spraying will be for piping. To obtain the necessary head, it might be necessary to pipe from some considerable distance upstream, the actual distance probably differing for each location. A delivery up to 4,000 gallons per hour should be allowed for and be available in the driest summers. Piping of 3-in. diameter necessary for this delivery could be obtained at approximately 2s. 6d. per foot.

Both piping and sprays should have an appreciable value at the conclusion of the salvaging operations. It should therefore be necessary to charge only depreciation of value against the salvage plan.

(*f*) *Submersion.*—Complete submersion in fresh water is the surest method of avoiding deterioration, and logs can be kept in sound condition for many years in this way. Tidal or brackish water is unsafe because of the possibility of infestation by marine borers. Deep water should also be avoided as this involves high cost of raising and recovery.

Submersion will halt the progress of insects, decay, stains, or desiccation, but as it cannot undo any damage that has developed in the logs, they should be submerged before deterioration sets in. Only shallow and fresh water submersion should be considered.

Wherever this method is practicable at reasonable cost, it is recommended that it be adopted. As it is believed to be under investigation by the Forests Commission and the State Rivers and Water Supply Commission, the method will not be covered further in this report.

5. Acknowledgments.

Grateful acknowledgments are made to the officers of the Victorian Forests Commission, who materially assisted in the surveys and gladly supplied information at their disposal, and also to Messrs. J. F. Ezard and Sons and to Bilston Bros., who co-operated in the conversion studies.

The Internal Lacquering of Tinplate Containers for Foods.

I. The Determination of Tin in Foods and a Survey of the Tin Content of some Canned Foods.

By L. J. Lynch, B.Sc.Agr., and J. F. Kefford, M.Sc.**

Summary.

The tin content of a series of canned foods marketed in Australia has been determined by a convenient routine method, and the results, with those of tasting tests, reveal the need for lacquered containers for some products, particularly fruit and vegetable juices. Commercial lacquers were tested for suitability as liners for orange juice cans, and a study of various methods of lacquer application indicates spray-lacquering into the made-up can as the most satisfactory technique.

1. Introduction.

The use of tinplate containers for foods is generally recognized to be limited by certain defects such as hydrogen swells, discolouration of the can and contents, and metallic taints in the product, and attempts are being made to overcome these disabilities by the internal lacquering of food cans.

There is at present no general agreement in the Australian canning industry as to which foods require lacquered cans, and the use of the latter seems to depend on the policy of the canner, some canners packing all products in lacquered cans, others using only plain cans.

An examination of a series of fruit, vegetable, and dairy products marketed in Australia was undertaken in order to indicate those which could with advantage be packed in lacquered cans. The examination included the determination of the tin content of the product, visual inspection of the can, and qualitative tests of flavour characteristics.

Little information is available from abroad regarding the composition of suitable can lacquers or the method of application to the tinplate, but reports received from time to time suggest that a fully satisfactory technique for lacquering has not yet been achieved. Experimental work was therefore commenced with commercial lacquers applied initially by rolling on to the plate but in later treatments by spraying into the made-up can. The testing of the lacquers and methods of application was carried out in conjunction with the current programme of fruit juice canning in this laboratory.

2. Experimental.

(i) *The Determination of Tin.*

(*a*) *Choice of Method.*—A volumetric method of tin estimation was desirable for the series of determinations involved in this work, but since the reliability of such methods had been questioned (Adam and

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* An officer of the Section of Food Preservation and Transport.

Horner)*, preliminary tests of the accuracy obtainable were necessary. Accordingly, the reproducibility and precision of a method based on that of Owe† were tested by applying the method to orange juice to which known amounts of tin had been added in the form of aliquots of a standard solution of tin obtained by dissolving A.R. tin in hydrochloric acid. The results, shown in Table 1, indicate satisfactory reproducibility and a recovery of 98.5 per cent. at a concentration of 22.3 mg. per litre, which was sufficiently accurate for the purpose. At concentrations below 20 mg. per litre the recoveries were high, but this did not invalidate the method, since such concentrations are unimportant from the point of view of tin contamination of canned foods.

TABLE 1.

Product.	Tin Added, Mg. per Litre.	Tin Recovered, Mg. per Litre.	Recovery, Per cent.
Orange juice	Blank	0·0 0·0	..
,, ...	5·6	7·7 7·7	137·5
,, ...	11·2	13·3 13·8 13·8	121·4
,, ...	22·3	21·0 22·1 21·8 21·9 21·8 23·2	98·5

(*b*) *Apparatus.*—To further facilitate routine determinations of tin, the stand illustrated in Plate 1 was constructed to hold six digestion flasks and also the Erlenmeyer flasks for the subsequent reductions. A framework of ¼-in. steam pipe supports a strip of brass gauze, 36 inches by 5 inches, on which the flasks rest. Shaped pieces of brass strip are bolted to the forward edge of the platform to hold the Kjeldahl flasks in position, and six Bunsen burners with extended stopcocks are mounted beneath on ½-in. gas pipe. The uppermost length of ¼-in. piping, on which are mounted six swan necks in ¼-in. brass tubing with pet-cocks, delivers carbon dioxide from a cylinder into the reduction flasks and also provides a support for the necks of the digestion flasks.

(*c*) *Sampling.*—After the can had been examined for vacuum and opened, 50-ml. samples of juice products were taken with a pipette; jams and dairy-products were transferred completely to a glass vessel, rendered homogeneous, and 50-g. samples taken by weight; fruits and vegetables were separated into liquids and drained solids and a composite 50-g. sample taken of these in proportion to their weights.

(*d*) *Analysis.*—The analytical procedure is described in detail for the convenience of commercial laboratories. The sample, in duplicate, was digested in a 300-ml. Kjeldahl flask with 50 ml. pure concentrated

* Adam and Horner, *J. Soc. Chem. Ind.*, **56**: 329T, 1937.

† Owe, Tidsskrift for Kemi og Bergvaesen, 3, 8 and 31, 1923

nitric acid and 10 ml. pure concentrated sulphuric acid until white fumes appeared. The digestions of products high in total solids, especially jams and dairy products, proved troublesome owing to frothing and were carried out in larger flasks under constant supervision. The digest was allowed to cool, 2 ml. of 30 per cent. hydrogen peroxide were added and the heating resumed. This process was repeated until all charred organic matter had disappeared and the contents of the flask were water-white. On cooling, the crystalline precipitate observed by Adam and Horner (*loc. cit.*) sometimes appeared, but was re-dissolved by adding 10 ml. distilled water and boiling. The clear digest was washed from the Kjeldahl flask and made up to 50 ml. with distilled water. A 20-ml. aliquot of this solution was diluted with 20 ml. distilled water in a 150-ml. Erlenmeyer flask and to it were added 5 ml. pure concentrated hydrochloric acid and 0.05 g. aluminium foil in small pieces. The flask was stoppered with a two-hole stopper having a short outlet tube and a tube extending to the bottom of the flask. The latter was connected to the carbon dioxide line on the stand described above and the gas bubbled briskly through the solution under gentle warming. When evolution of hydrogen had ceased, the solution was boiled for a short time, allowed to cool, and excess N/200 iodine solution added from a graduated pipette while carbon dioxide still passed. The flask was removed from the stand and the solution back-titrated with N/200 sodium thiosulphate solution from a 2-ml. burette using starch as an indicator.

(ii) *Application of Lacquers.*

It was initially arranged to apply a series of lacquers by roller-coating the plate in a commercial varnishing machine. The lacquers were obtained locally and were manufactured for stoving at 350°F. for 90 minutes. After lacquering, the sheets were cut into strips and formed into cans in the usual manner. The protective film in cans made in this way was found to be defective in two respects. Conspicuous charring of the lacquer occurred along the side seam during soldering, and abrasions during the forming of the cylinder and stamping of the ends were common. In addition, the incorporation of dust particles into the film before drying pointed to the necessity of a dust-free atmosphere for work of this nature, since continuity of the film is essential.

These observations suggested that deficiencies in the basic film might be rectified by a second coat of lacquer sprayed within the can. The method was tested but found impracticable, for the reason that penetration of the second coat through scratches in the primary film caused the latter to lift, thereby exposing considerable areas of the underlying tinplate. Moreover, the buffering action of the air prevented deposition of atomized material in those parts of the can adjacent to the corners. As a result, excessive lacquering was necessary to obtain a complete cover, and such overlacquering was invariably accompanied by charring during the stoving process.

Further modification consisted in masking from the rollers those areas of tinplate which were subsequently to form the seam, with the object of avoiding solder burn. These areas were covered by a second spray coat applied to the made-up can. In this case the buffering effect previously described was eliminated by spraying the cylinder without the end attached. This technique effected considerable improvement,

but it suffered from the disadvantage of double handling which would be time-consuming and costly in commercial practice, while the lacquer film though continuous was somewhat uneven in thickness. These difficulties suggested a change in technique wherein prelacquering of sheet tinplate was entirely discarded.

In the routine method now practised, one flange of the open cylinder is first sprayed in the hand; this sprayed flange is attached by electro-magnets to a turntable, and the inner surface coated by directing the spray gun obliquely within the can during rotation at 200 to 250 revolutions per minute. The can ends or lids are lacquered in the same manner. Preliminary spraying of the rim in contact with the turntable is necessary since, by reason of its shape, deposition of lacquer does not occur in this part of the can during rotation.

The turntable, which is suitable for small scale experimentation, consists of three light metal arms mounted on a horizontal spindle, which is belt-driven by a small electric motor (shown in Plate 4). Attached to the turntable are three double-pole electro-magnets which may be set at various radii according to the size of the can. The magnets are permanently connected to the current supply, and a conveniently placed footswitch is used to start and stop the motor as required.

No attempt has been made to develop in detail suitable equipment for the internal lacquering of cans on a commercial scale. The introduction of a double belt conveyor system into the can production line should serve to rotate the can bodies past a synchronized spray gun at a fixed point, whence they could be delivered to a suitable type of lacquer oven. With respect to the ends it is felt that these may be lacquered in the plate, provided that the strip feed press is adjusted to eliminate damage to the film. In this connexion attention is particularly directed to the guides, as these have been the cause of such damage during the present series of experiments (see Plate 3, Fig. 2).

The effect of the lacquer film on the efficacy of the rubber sealing compound filled into can ends has not yet received consideration. The degree of vacuum attained by hot sealing of the can at a juice temperature of 170°F. has been of the order of 14 inches of mercury, and no loss of vacuum has occurred during storage. It is possible, however, that the sealing compound, when covered with lacquer film, may not hold a 25-in. vacuum in a vacuum-sealed can. Therefore, the lids are now filled after, instead of before, lacquering. There is the additional reason for this step that the stoving temperature of 350°F. exceeds the temperature 290°F. above which depolymerization of the rubber sealing compound occurs with consequent deterioration in its ageing properties.

(iii) *Testing of Lacquers.*

In order to evaluate the merits of the respective lacquers and methods of application, the cans were used for the storage of Parramatta orange juices of the same picking maturity, and, after definite periods, viz., 15 weeks and 26 weeks, the juices were analysed for dissolved tin. A standard processing method was adopted for the preservation of the orange juices, and this was maintained constant throughout the work in order to simplify the interpretation of tasting tests upon which the judgment of the various lacquers was, to some extent, based. The juice was expressed from peeled oranges, strained, deaerated at 29-in. vacuum,

pasteurized at 205°F., canned at 170°F., sealed, and cooled by immersion in water. The apparatus was constructed of stainless steel and glass with the exception of the pasteurizer and cooler, each of which consisted of a jacketed coil of block-tin tubing.

All samples of commercial juices and those prepared at this laboratory were submitted to a selected panel of seven tasters for examination. Judgment was based on the criteria of appearance, including colour and clarity; smell, embracing aroma and foreign odours; and taste, including sugar-acid balance and off-flavours. Detailed results of the tasting tests on individual juices are not tabulated below since their value lies chiefly in determining the merits of different processing methods. The qualitative but nevertheless definite conclusions of the panel with regard to off-flavours and taints are included in the discussion.

3. Results.

Table 2 contains the results of the inspection and analysis for tin of commercial products marketed in Australia. The capitals, A, B, &c., refer to individual canners. The tin content of juices is expressed in milligrams per litre and that of vegetable products, fruits, jams, and dairy products in milligrams per kilogram.

TABLE 2.

Product.	Source.	Type of Can.	Weeks in Can.	Mean Tin Content.	Remarks.
Pineapple Juice	A, Australia ..	Plain ..	2	80	Feathered, stained
Pineapple Juice	A, Australia ..	Plain ..	..	155	Feathered, stained
Pineapple Juice	B, Australia ..	Plain ..	..	113	Feathered
Pineapple Juice	C, U.S.A. ..	Plain ..	..	277	Badly feathered
Pineapple Juice	D, U.S.A. ..	Plain ..	..	115	Feathered
Pineapple Juice	Experimental*	Plain ..	8	80	Feathered
Pineapple Juice	Experimental*	Single lacquer	8	11	
Pineapple Juice	Experimental*	Double lacquer	8	6	
Grapefruit Juice	C, U.S.A. ..	Plain ..	..	275	Badly feathered
Orange Juice ..	Experimental*	Plain ..	26	205	Badly feathered
Orange Juice ..	Experimental*	Single lacquer	26	35	
Orange Juice ..	Experimental*	Double lacquer	26	28	
Orange Juice ..	Experimental*	Glass bottle	26	2	†
Tomato Juice ..	E, Australia ..	Plain ..	..	82	Lightly feathered
Tomato Juice ..	F, U.S.A. ..	Plain ..	..	67	Lightly feathered
Prune Juice ..	G, U.S.A. ..	Plain ..	..	251	Feathered
Prune Juice ..	H, U.S.A. ..	Plain ..	..	325	Feathered
Apricade ..	F, U.S.A. ..	Plain ..	..	101	Feathered, stained
Sauerkraut Juice	F, U.S.A. ..	Plain ..	..	42	Badly stained
Asparagus ..	J, Australia ..	Plain ..	28	186	Very heavily feathered and stained
Asparagus ..	J, Australia ..	Plain ..	124	195	As above

* Processed at this laboratory.

† The comparatively high tin content for glass-packed juice may be attributed to the use of a block-tin pasteurizer.

TABLE 2—*continued.*

Product.	Source.	Type of Can.	Weeks in Can.	Mean Tin Content.	Remarks.
Asparagus ..	J, Australia ..	Plain ..	168	212	As above
Asparagus Soup	J, Australia ..	Plain ..	24	197	Heavily feathered and stained
Tomatoes ..	K, Australia ..	Plain ..	56	66	
Tomato Soup	J, Australia ..	Plain ..	8	42	
Green Peas ..	J, Australia ..	Plain ..	8	16	
Brussels Sprouts	J, Australia ..	Plain ..	4	21	Badly stained
Cauliflower ..	J, Australia ..	Plain ..	4	12	Badly stained
Peaches ..	K, Australia	Plain ..	60	30	
Pineapple ..	K, Australia	Plain ..	..	41	
Plum Jam ..	K, Australia	Plain ..	20	30	
Marmalade ..	K, Australia	Plain ..	44	51	
Raspberry Jam	K, Australia	Lacquered	36	43	Lacquer film burnt and ruptured
Reduced Cream	L, Australia ..	Plain ..	..	64	Stained
Condensed Milk	L, Australia ..	Plain ..	..	30	

The results obtained indicate the necessity for reliable can lacquers for many foods at present packed in unprotected cans. Such lacquers could be applied with particular advantage to containers for certain products, e.g., fruit juices and asparagus preparations, which apparently have a specific corrosive action on the can and show exceptionally high tin contents. Although recent evidence (Adam and Horner, *loc. cit.*) seems to show that quantities of tin greater than are contained in the most heavily contaminated canned foods are rapidly eliminated, when taken orally, without toxic effects on the human organism, the Pure Foods Acts in Great Britain and the Australian States set the limit for the tin content of canned foods at 2 grains per lb. (285 mg. per kg.). Table 2 indicates that several fruit juices of American origin were very close to this limit, and in one case the permissible tin content was exceeded.

Table 3 records some of the tests on commercial lacquers. "Rolling lacquer" refers to the lacquer applied in the varnishing machine to sheet tinplate in single (S) or double (D) coat. "Spray laquer" refers to the lacquer sprayed into the made-up can.

These figures are set out in order to indicate the usefulness of tin determinations as a means of deciding the relative merits of different lacquers and methods of application.

There are some apparently inconsistent results, marked (*), but in each of these cases the cans, on examination, showed gross tooling damage of the type illustrated in Plate 3, Fig. 2. Therefore the tin content of the product must be interpreted in conjunction with the results of the visual examination of the can. Analysis along these lines, of the figures obtained, led to the adoption of the following arbitrary standards; less than 30 mg. tin per litre indicates a good lacquer treatment, greater than 100 mg. tin per litre, a poor lacquer treatment. It is considered that tin concentrations in canned food products greater than 30 mg. per litre are unnecessary and avoidable by suitable lacquer treatments.

TABLE 3.

No.	Rolling Lacquer.	Spray Lacquer.	Mean Tin Content after 15 Weeks' Storage, Mg. per Litre.	Mean Tin Content after 26 Weeks' Storage, Mg. per Litre.
1	T.V.2 (S)	.. .. ..	43	..
2	T.V.2 (S)	T.V.2	18	22
3	T.V.2 (S)	T.V.5	24	..
4	T.V.2 (S)	T.V.6	45	84
5	T.V.3 (S)	.. .. ..	48*	36
6	T.V.3 (S)	T.V.3	20	22
7	T.V.3 (S)	T.V.5	..	36
8	T.V.3 (S)	T.V.6	31	33
9	T.V.4 (S)	.. .. ..	37	60
10	T.V.4 (S)	T.V.4	15	27
11	T.V.4 (S)	T.V.5	..	45
12	T.V.4 (S)	T.V.6	..	39
13	T.V.3 (D)	.. .. ..	83*	73
14	T.V.3 (D)	T.V.3	14	97*
15	T.V.3 (D)	T.V.5	27	76
16	T.V.3 (D)	T.V.6	..	39
17	T.V.4 (D)	.. .. ..	33	68
18	T.V.4 (D)	T.V.4	15	23
19	T.V.4 (D)	T.V.5	21	46
20	T.V.4 (D)	T.V.6	16	48
21	.. .. ..	T.V.4 (S) ..	..	35
22	.. .. ..	T.V.4 (D) ..	..	28
	Plain Can (Mean of 10)	.. .. ..	126	205

In all, thirteen commercial lacquers, manufactured in Australia, Great Britain, and U.S.A., were tested, but eight of these were rejected as unsatisfactory for application to tinplate. Of those remaining, T.V.2, T.V.3, and T.V.4 are gold stoving lacquers, T.V.5 and T.V.6 are transparent finishing lacquers. It is evident that the finishing lacquers provided little additional protection to the rolling lacquers and moreover they proved to be fragile and gave a bitter taint to the juice. Rolling lacquer T.V.2 afforded adequate protection but was also eliminated because of lacquer taint in the product. Lacquers T.V.3 and T.V.4 were outstanding in ease of dilution for spraying and in "spreadability" on the surface of the tinplate. When applied in either single or double coat before making up (Nos. 5, 9, 13, 17) they achieved only moderate protection, as was to be expected for the reasons indicated above; but when the same lacquer as the rolled coat is sprayed into the made-up can (Nos. 6, 10, 14, 18) the protection was uniformly good. However, the double handling and double stoving involved in this lacquer treatment render it uneconomic, and also the heavy lacquer coat is unattractively dark in appearance. On the other hand, these same lacquers when applied by the present spraying method are free from these disabilities and give comparable protection (Nos. 21, 22). It is doubtful whether the difference between singly and doubly applied T.V.3 and T.V.4 is significant, and it is likely that in commercial practice single coats of these lacquers will be adequate.

4. Discussion.

The present study has afforded evidence that by the correct application of appropriate can lacquers, the appearance of a canned product and its container, and the flavour and aroma of the product, may be considerably improved.

The action of a canned product upon the container may be such as to render the inner surface of the can unsightly in appearance owing to "feathering" (Plate 2, Fig. 2), to black sulphur-staining, or to a combination of the two. Products rich in dissolved tin exhibited extensive feathering, which appears to be an intensification of the inherent crystalline pattern on the tinplate, and this defect was combined with sulphur-staining in asparagus products, brussels sprouts, cauliflower, reduced cream, and sauerkraut and pineapple juices. Not only would internal lacquering eliminate these defects, but the pleasing golden appearance of a correctly applied gold stoving lacquer would make a positive contribution to the appeal of all canned products.

Foods packed in unprotected cans possess, when opened, a "metallic" odour which is usually dissipated after a short exposure to the atmosphere. In some foods, however, e.g., asparagus, pineapple, and peaches, a metallic taste which persists indefinitely is often evident. This unpleasant taste is readily discernible but is apparently accepted by the consumer as inseparable from canned foods. The metallic taste was invariably detected in orange and pineapple juices packed in plain cans but was completely absent from juices stored in correctly lacquered cans.

It has been observed that the plain can, as well as imparting a metallic taste, has a further characteristic effect on the flavour of a number of fruit and vegetable products. The effect was first detected by the tasting panel during the examination of pineapple juices, the natural aroma and bouquet of which were impaired by a nauseating taste and odour. On the other hand, identical juices packed in lacquered cans possessed the full fresh flavour of the fruit. The same observation has been extended to a number of other products, including orange, grapefruit, and sauerkraut juices and asparagus tips and asparagus soup. The odour and taste may best be described as putrid, but there is ample evidence that it is not caused by putrefactive breakdown of the juice. The problem as to the nature of the degradation in flavour is receiving further study, since it is most important that this action of the unprotected can should be confirmed, furnishing as it does a potent reason for the more widespread use of internal lacquers in tinplate containers for foods.

5. Acknowledgments.

The authors are indebted to Mr. F. Dickson for chemical and technical assistance and to Mr. P. R. Maguire for Plates 1, 2, 3, and 4. They also wish to record that enthusiastic co-operation was received from many commercial firms, particularly Messrs. H. Jones and Co. Pty. Ltd., Messrs. Lewis Berger and Sons Pty. Ltd., and Messrs. Richard Hughes Pty. Ltd.

A New Dressing for Fly Struck Sheep.

By Martin R. Freney, B.Sc., and N. P. H. Graham, B.V.Sc.**

Part I.—The Compounding of the Dressing and Laboratory Trials.

There has been a long-felt want in Australia for a dressing, to be used on fly-struck sheep, which, while being efficient from the point of view of relieving the sheep of its maggot infestation, avoids the undesirable features of many of the present dressings.

In 1935 the Council (Freney, Mackerras, and Mackerras, 1935, 1936)† evolved a dressing which, while not irritating to the skin, was efficient in ridding the sheep of its infestation. This dressing, known as glycerine diboric, incorporated a new feature, in that boracic acid was the main larvicidal compound present. Unfortunately, owing to the increase in the price of glycerine, the cost of this dressing became prohibitive. It had been so satisfactory, however, that an attempt was made to evolve another dressing containing a high percentage of boracic acid which could be made cheaply. Eventually the dressing described in this article was devised and tested.

Using boracic acid as the main larvicidal and antiseptic compound, it was decided to try and combine it in an emulsion with an oil which is toxic to maggots, and also possibly repellent to flies. A number of oils, which are cheap and are reputed to be parasiticidal, were therefore tested to determine whether or not they were irritant to the skin of the sheep. It was considered that to estimate the irritant quality of these oils by applying them undiluted to the skin of the sheep would be too severe a test. The tests were therefore carried out using one part of each oil dissolved in three parts of olive oil, which is bland to the skin.

The method by which the materials were tested was to shear close to the skin an area of 6 inches by 6 inches on the side of the sheep and rub the oil mixture thereon until the skin was quite soaked. The results of these tests, in which the sheep were kept under frequent observation for four weeks, are given below:—

Ol. abietis, Ol. camphor rect., Ol. eucalypti. The skin at no time showed signs of irritation.

Ol. cade, Ol. picis, Ol. pini sylvestri, Ol. sassafras, Ol. terebinthae. A slight swelling developed one day after application but no scab formed.

Ol. betulae (crude). Some slight hardening of the skin was detected 7 to 14 days after application, but it appeared quite normal at the end of the experiment.

Ol. betulae (pure), Ol. succini. The area to which this was applied became red and swollen, and at the end of the experiment was covered by a thin scab.

Thus, *Ol. abietis, Ol. eucalypti,* and *Ol. camphor* were found to be non-irritant under the test conditions, and as *Ol. camphor* was the most readily emulsified, further experiments were undertaken with it.

* Officers of the Council's McMaster Animal Health Laboratory, Sydney.

† Freney, Mackerras, and Mackerras (1935).—*J. Coun. Sci. Ind. Res.* (Aust.), 8, (3): 161. Freney, Mackerras, and Mackerras (1936).—*Ibid.*, 9, (1): 11.

Additional reasons for this selection were that a 10 per cent. solution of *Ol. eucalypti* in pale mineral oil was found by Mulhearn (1931)* to be insufficiently toxic to kill or remove maggots, and a similar 25 per cent. solution scalded and blistered sheep, while *Ol. abietis* is a more expensive oil than *Ol. camphor.*

Compounding the Dressing.

The recommended glycerine-boric acid dressings (Freney, et al., *loc. cit.*) depend for toxicity on their high percentage of boric acid, which is a stomach poison, and which, by remaining on the struck area, delays the development of restrikes. It seemed desirable, therefore, to incorporate as much boric acid as possible in any new dressing which was devised, and since the borates of potassium are more soluble than those of sodium, attempts were made to emulsify *Ol. camphor* in a saturated solution of potassium borate with the aid of an emulsifying agent. Potassium oleate was found to be satisfactory for the latter purpose, and emulsions of *Ol. camphor* in potassium oleate-potassium borate mixtures were subjected to laboratory tests to determine their value as dressings for struck sheep.

Preliminary Results.

Experiments with dressings of this nature on over 30 sheep indicated that they were not undesirably irritant. When applied to strikes they gave relief by killing younger maggots and driving off older ones, many of which were killed. Some observations suggested that the dressing also had value as a fly repellent. Details of the earlier experiments are not given because, although the results were considered promising, the dressings have subsequently been modified slightly to improve them in certain respects, and the discussion which follows is therefore limited to results obtained with those mixtures approximating in composition to the emulsion eventually found to be most satisfactory.

Preparation of the Dressings.

The potassium hydroxide is dissolved in the total volume of water to be used in compounding the dressing (for percentages of ingredients by weight see page 315). The boric acid is powdered and dissolved in the potassium hydroxide solution, using heat if necessary. The oleic acid is added to the oil of camphor and small amounts of the aqueous solution of the borate are added with vigorous stirring. When about one-quarter of the solution has been added in this way, and a creamy emulsion has been obtained, it is poured slowly and with constant stirring into the remainder of the potassium borate solution. The stability of the emulsion thus obtained is greatly improved by heating to just over 60°C., with stirring, and then cooling rapidly whilst the stirring is continued. It is not considered that this method is the only one satisfactory for preparing stable emulsions from these ingredients, but it has been found convenient in the present work.

Laboratory Tests of the Dressings.

Preliminary trials of the ingredients of the dressing and of a compounded mixture were carried out in collaboration with Drs. I. M. Mackerras and M. J. Mackerras of the Division of Economic Entomology, Canberra. The results were sufficiently promising to

* Mulhearn (1931), N.S.W. Dept. Agr. Sci. Bull. 37, p. 31.

suggest that the dressing was worthy of further investigation if its formula were modified. As a consequence, a number of tests have been carried out at the McMaster Laboratory by the authors with the separate ingredients, and also with a dressing of the following percentage composition by weight:—

	Per cent.
Potassium hydroxide	4.9
Boric acid	12.5
Oil of camphor	13.2
Oleic acid	2.5
Water, to make	100.0

The ingredients of the emulsion were tested to determine whether they were irritating to the skin by applying them liberally to the normal skin after close shearing. The results were as follows:—

Camphor Oil.—If used *undiluted* this is irritant, the degree of irritation, i.e., whether moderate or severe, depending largely upon the sensitivity of the skin of the sheep to which it is applied. A solution of 40 per cent. oil of camphor in olive oil showed transient reddening but no irritation.

Potassium oleate.—This was tested in the form of 5 per cent. aqueous solution, which caused a mild but transient swelling on one of the two sheep used. No scabs developed.

Potassium borate.—This was tested in the form of 10 per cent. and 15 per cent. solutions, made by dissolving boric acid in warm potassium hydroxide solutions, in the proportions of 16.2 of H_3BO_3 to 6.4 of KOH. The wool became harsh after the application of these solutions—due probably to the formation of crystals of potassium borate in the fleece—but the skin showed no signs of irritation.

Tests with oleic acid or potassium hydroxide are not discussed, as these ingredients are not present uncombined in the dressing.

Compounded Dressings.—These preliminary tests were designed to determine whether the dressing had an irritant action on the sheep's skin, and to obtain data regarding its larvicidal powers.

The irritation tests were carried out on fifteen sheep in the same manner as were those with the separate ingredients (see below). Animals less than a year old were used, as it was considered that these would have the most delicate skins. In nine of these sheep the dressing had no irritant effect whatever; in one a slight and transient oedema appeared on the first day, but left no after-effects; in three a slight scurfiness was detected, while in the remaining two sheep a very thin scab appeared over parts of the area. Subsequent observations on a large number of strikes dressed with this preparation in the field have also shown that the dressing has little or no irritant action on the skin.

Laboratory Tests on Strikes.

Some strikes, induced by placing maggots on the skin of the sheep, were dressed with this preparation after extensive lesions had developed. Observations were then made on the qualities of the dressing as follows:—

(*a*) *Penetration.*—If the strike were shorn in the manner normally adopted in the field, the dressing penetrated the fleece over the struck area excellently, and spread rapidly.

(*b*) *The Effect on the Maggots.*—Toxicity tests on the dressings were carried out as follows:—10 third-instar maggots were immersed for periods varying from ½ minute to 15 minutes. All were killed. As far as maggots collected from dressed areas are concerned, of 70 third-instar maggots, which were collected from one strike, only five flies emerged although 57 of the maggots pupated. In another test in which an unknown number of maggots were collected, 151 pupated and 69 flies emerged. In a third test, numerous maggots were collected, 30 of which pupated and eleven flies emerged. In each of these tests the pupae were kept under observation for five months.

These tests indicated, therefore, that a certain number of the maggots which leave the struck area when the dressing is applied are capable of developing into flies, but this was not considered very important, since under field conditions, however undesirable, most of the maggots escape while a strike is being shorn in preparation for dressing, and many of these will develop into flies.

(*c*) *Prevention of Restrike.*—It was apparent from the amount of boric acid present, and from the presence of oil of camphor which is toxic to younger maggots, that the dressing would have some value in preventing restrike. Just what value it would have would naturally depend on the abundance and activity of fly in the field, on the susceptibility of the sheep, and on climatic conditions. In order to standardize laboratory tests on restrike, the importance of each of these factors must be assessed. In view of the difficulty of doing this we have confined our consideration of the ability of the dressing to prevent restrike, to experiments which were carried out under field conditions. These are discussed in Part 2 of this paper.

(*d*) *Effect on Strike Wounds.*—Application of the dressing to strike wounds neither intensified nor prolonged the lesions caused by the maggots.

(*e*) *Effect on Healing.*—The thickness of the scabs which formed over lesions on dressed areas was not abnormal and depended largely upon the amount of damage done by the maggots prior to dressing. These scabs began to lift within a week of dressing and were dry and healthy.

(*f*) *Toxicity to the Sheep.*—In view of the idosyncrasies of individual sheep and the lack of suitable means of assessing toxicity of dressings, only observations of a general nature were made on this point. No sheep died or appeared ill following the application of the dressing.

Final Composition of the Dressing.

Irritation tests with similar emulsions showed that no irritation resulted if 3.7 per cent. oleic acid were present as potassium oleate. The amount of potassium borate which separated on standing was estimated, and the amounts of potassium hydroxide and boric acid used were reduced to prevent or minimize this crystallization.

The percentage by weight of the ingredients in the mixture used for field tests after these modifications had been made, are as follows:—

	Per cent.
Potassium hydroxide	4.1
Boric acid	10.05
Oil of camphor*	13.2
Oleic acid	2.5
Water, to make	100.0

This dressing has for brevity been called "C.B.E." (a convenient abbreviation for camphor-boracic-emulsion) and it is referred to by this term in the second part of this paper, which describes the field trials which have been carried out and the results obtained.

Part 2.—Results obtained in Field Trials.

In Part 1, one of us (M.R.F.) discussed the compounding of a potassium-borate–camphor-oil emulsion (Dressing C.B.E.) for the treatment of fly-struck sheep. An account was also given of the tests carried out under laboratory conditions.

In practice, approximately 90 per cent. of the fly strikes in ewes are crutch strikes. These differ fundamentally from body strike, especially in that the susceptible part of the crutch or breech is, as a rule, continually wetted or washed with urine.

Because of this particular local condition, a dressing which might prove satisfactory in the treatment of artificial body strikes need not necessarily be effective in the treatment of crutch strikes, and it was therefore decided to test dressing C.B.E. against natural crutch strike under field conditions.

In the past a considerable amount of attention has been focussed on the degree of protection given by a dressing against restrike, and this has, to a large extent, been used as a criterion of the efficiency of dressings. Restrike, under field conditions, is a very variable phenomenon depending on the degree of fly activity, on the conformation of the sheep, and also on chance.

In an endeavour to obtain the most favorable conditions for restrike, it was decided to confine the tests to properties situated in north-western New South Wales and southern and central Queensland, where fly strike is notoriously prevalent. Arrangements were therefore made to carry out tests on several properties which could be grouped geographically into three areas. The southernmost, the Gilgandra-Warren-Coonamble area, lying some 200 to 300 miles north-west of Sydney, the Moree-Walgett-Dirranbandi area extending along the New South Wales-Queensland border and the adjacent country, and the Corfield-Winton area in Central Queensland, lying some 400 miles further north. The properties, therefore, were scattered along a line running north and south for 600 miles. It was hoped with this wide dispersion that we would be likely to get a bad fly wave in either one or the other of the groups of properties.

Arrangements were made to start the tests in the autumn of 1938, and they were carried out on the various properties from that time until the autumn of 1939.

* Owing to the present difficulty of obtaining many imported oils and drugs, attention is being given to the problem of finding a substitute for oil of camphor; as yet no satisfactory substitute has been found.

Each property was supplied with one gallon of dressing and given full instructions for its use and the observations it was desirable to make. There was, therefore, a certain amount of uniformity in the method of application and the observations recorded. On one property, the method of use differed widely from the instructions sent out, and the observations were therefore discarded.

The instructions given were briefly as follows: (*a*) The dressing was not to be used until such times as a definite fly wave was in progress. (*b*) It was only to be used on sheep which could be individually identified. (*c*) The struck area was to be shorn and a liberal amount of the dressing lightly rubbed on.

In addition to these general instructions, a small pocket record book was sent to each tester. In this were tabulated the observations which were to be made, a specimen page of the book being shown below.

Date dressed .... Sheep No.........................
Site .. .. .. [*Crutch*] [*Tail*] [*Body*] [*Head*]
Severity .. .. .. [*Mild*] [*Moderate*] [*Severe*]

Appearance after Three Days.

Wound .. .. [*Healing*] [*Inflamed*]
Scab .. .. .. [*Normal*] [*Cracked and Pussy*]
Does scab extend beyond area of strike .. .. [*Yes*] [*No*]
Are live maggots present .. .. .. [*Yes*] [*No*]
Does wound attract flies .. .. .. [*Yes*] [*No*]
Weather since dressing .. .. [*Fine*] [*Muggy*] [*Rain*]

Appearance after Two Weeks.

Wound .. .. .. [*Healed*] [*Healing*] [*Inflamed*]
Scab .. .. .. [*Adherent*] [*Lifting*] [*Absent*]
Are live maggots present .. .. .. [*Yes*] [*No*]
Does wound attract flies .. .. .. [*Yes*] [*No*]
Is wool growing over area .. .. .. [*Yes*] [*No*]
Weather since examination [*Fine*] [*Muggy*] [*Rain*]
Date of restrike ....
Please check Sheep No...

From this reproduction it will be seen that the observations on each sheep were to be made on three occasions and to cover certain definite points, namely, the healing of the wound, the degree of scab formation, presence of maggots, flies, &c., and the weather conditions. Definite standards were set down as to what was to be called a "mild," "moderate," or "severe" strike, depending on the size of the struck area and the number of maggots present.

Unfortunately, there was very little fly strike in the northern areas from the autumn of 1938 onwards, so that our data is drawn almost entirely from north-western New South Wales and southern Queensland.

In these areas the dressing was tried on seven different properties by graziers, 185 struck sheep being dressed. In addition to this, a trial involving 52 sheep was carried out in the Walgett district by one of us (N.P.H.G.) during a severe fly wave, and another trial was carried out on the National Research Station, Gilruth Plains, Cunnamulla, Queensland, under the direction of Dr. Riches. In the latter trial a direct comparison was made between dressing C.B.E. and glycerine-diboric dressing on struck sheep in the same flock, 95 strikes being dressed with the former and 105 strikes with the latter.

Most of the tests were carried out by graziers during the 1938 autumn and spring, when there was considerable fly activity on most of the properties. The results were, as a whole, quite satisfactory, 142 sheep being dressed and only nine being restruck within fourteen days. Of these nine sheep, eight were restruck within one week. Most of the restruck sheep were on one property, No. 6, where the test was carried out during an exceptionally severe fly wave.

Observations on the incidence of crutch strike during the course of other field trials had suggested to us that these restruck sheep might be of a highly susceptible type, and be extremely difficult to protect from restrikes. To check this point one of us carried out the above-mentioned special trial at Walgett on sheep whose fly strike record for the previous eighteen months was known. This test was carried out during a period of severe fly strike in the autumn of 1939.

The results of this trial were very similar to those obtained on property No. 6, 52 sheep were treated of which three were restruck and five had eggs deposited on them within three days. One which was restruck and two on which eggs were deposited were not again struck during the three weeks the sheep were under observation. The remaining five were restruck on at least two, and often three, other occasions during the three weeks. These five sheep are among a group which have been under observation for a period of two years, during which they are known to have been struck on from 15 to 27 occasions. They are all very wrinkly sheep, the crutches of which are perpetually damp with urine, even when the wool is closely shorn off, and the restrikes took place on what was, virtually, bare skin damp with urine.

In all these cases the struck area outside the urine-saturated portion had healed cleanly and quickly, the restrikes occupying but a small portion of the original area.

Both in these tests and the test carried out at Gilruth Plains, healing has been quite satisfactory and seemed at least as good as that obtained with glycerine-diboric dressing.

The scab formed over struck areas to which C.B.E. was applied varied with the degree of damage done to the skin by the maggots prior to dressing, indeed in some cases a heavy, cracked, pus-containing scab was present over parts of the struck area before any dressing was applied. Where the damage to the skin was slight, the scab was thin and pliable. There was no evidence, therefore, that the dressing itself increased scab formation, and in no case was there scab formation outside the area originally struck. In those cases in which no restrike occurred, the strike wound healed rapidly and cleanly, the scab lifting and wool growth starting within fourteen days.

Conclusions.

Dressing C.B.E. was tested on a large number of crutch strikes in the field under conditions favorable for fly strike. Although restrikes occurred in a small number of cases, C.B.E. proved as satisfactory as glycerine-diboric dressing.

Our own experience of treating sheep with the dressing, together with the experience of those graziers who assisted us by carrying out tests under moderately controlled conditions, would indicate that

1. The dressing is easy to apply and penetrates the wool much more readily than glycerine-diboric. Owing to its shampoo-like action it is easy to work through matted wool over a strike.

2. It wets a raw surface satisfactorily.

3. Maggots are rapidly driven off the dressed area and many are killed within a few minutes.

4. In no case did we find maggots surviving on a struck area which had been in contact with the dressing.

5. When freshly applied the dressing seems to have a repellent action. Both the blowflies and the small bush flies leave the struck area and will not again settle on it. This effect, however, only lasts for one or two days and is, therefore, of minor importance so far as restrikes are concerned.

6. All adult flies coming in contact with the dressing are killed instantly.

7. Although the sheep may show signs of slight irritation when a strike is dressed, it is of very short duration and seems to be mainly due to the increased activity of the maggots as they crawl away from the dressed area.

8. The strike wound heals readily, and there is no evidence that the dressing has any harmful effect on either the skin or the wound.

9. The amount and character of the scab on a struck area is to a very large extent determined by the damage done to the skin by the maggots before the dressing is applied.

10. Wool to which the dressing is applied remains free and does not become matted.

11. The addition of colouring matter to the dressing would greatly facilitate its application, as it would then be possible to see clearly the area to which it has been applied.

12. These trials, together with the one conducted at Gilruth Plains, suggest that dressing C.B.E. is superior to glycerine-diboric dressing in its ability to penetrate the wool and on account of its lower viscosity, and is at least equal to it in its larvicidal and healing properties.

It is extremely doubtful if any dressing at present known will protect certain highly susceptible types of sheep from restrikes during periods of intense fly activity. To do so, a dressing would have to retain strong repellent properties over a long period or would have to remain adhering to the skin and retain its larvicidal or ovicidal properties in spite of being continually washed with urine.

Acknowledgments.

We wish to express our thanks to all those graziers who so kindly assisted us by carrying out these trials, for making sheep available and for the trouble they took in making the necessary observations. Our thanks are also due to Drs. I. M. and M. J. Mackerras of the Division of Economic Entomology, Canberra, for the trials they conducted for us in their insectaries, to Dr. Riches for supervising the trial at Gilruth Plains, and to Mr. D. A. Gill of the McMaster Laboratory for his help and criticism in designing the tests and correlating the results.

Studies on Fly-strike in Merino Sheep.

No. 3.—The Influence of Fly-strike and Conformation on Body-weight and Fleece-weight of Merino Sheep at "Dungalear", New South Wales.

By Dudley A. Gill, M.R.C.V.S., D.V.S.M. and N. P. H. Graham, B.V.Sc.†*

Summary.

Advantage has been taken of the presence at Dungalear Station, Walgett, of a flock comprising A, B, and C class sheep, half of which had been protected from breech strike by the Mules operation, to study (*a*) the effects of breech strike on body weight and wool production, and (*b*) the relative merits of A, B, and C class sheep as wool producers, under conditions which permitted the masking effect of differences in susceptibility to breech strike to be allowed for.

The adverse effect of breech strike on body weight and wool production depends on the number and the severity of the strikes incurred. It was found that the average fly-strike incidence in a flock of this type reduced the fleece production of the whole flock by approximately 5 ounces per sheep. This significant loss, amounting to about £16 per 1,000 sheep when greasy wool is worth 1s. per pound, is due to interference with wool growth and must be added to the many other costs of fly-strike.

The extent to which the greater incidence of fly-strike in C and B class sheep can mask their relative merits as wool producers when compared with A class sheep, is shown by the fact that unstruck C's produced 11 ounces, and unstruck B's 4 ounces, more greasy wool per head than unstruck A's, but when the normal incidence of fly-strike was taken into consideration the advantage of the C's was reduced to 4 ounces per head while that of the B's was eliminated altogether.

Tenderness of wool was only associated with fly-strike in some of those sheep which had incurred severe strikes; otherwise there appeared to be no connection.

The fleeces of the A class sheep tended to be slightly longer and "stronger" than those of the B and C class sheep but were estimated to give a slightly higher yield of clean scoured wool.

1. Introduction.

Observations have been made from time to time on the effect of fly-strike on body-weight and wool production in an endeavour to assess the economic loss it causes the grazing industry. On very few occasions, however, have accurate strike records been kept on any number of sheep, and on still fewer occasions has any attempt been made to determine the effect of these strikes on the body-weight and wool production. Mackerras (1936) and Belschner (1937) mention the adverse effect on body-weight and wool production resulting from fly-strike and the consequent economic loss, especially among lambs, but their statements appear to be based on general observations rather than on experimental data.

Although the trial at "Dungalear" was not designed to assess the economic loss due to fly-strike, it was found that some information on these losses could be obtained from the data which had been collected in conjunction with the trial of Mules' operation. For that purpose the sheep had been classified, according to conformation, by the method

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described earlier (Gill and Graham, 1938, 1939) into A, B, and C class sheep, half of each of these three groups being operated upon and the other half being left as controls.

As a result of the operation, relatively large groups of sheep, originally placed in either B or C class, remained free from strike during the year. A comparison of them with untreated B and C class sheep which had been flystruck on one or more occasions was, therefore, possible. The reason for the scarcity of information on the effect of fly-strike on body-weight and wool production has been the difficulty of keeping an adequate control group free from strike. It will be realized that this difficulty was obviated in the "Dungalear" trial.

2. Observations on Body-weight in the "Dungalear" Trial.

The sheep at "Dungalear" were weighed at shearing time in August 1938. No pre-experimental weights were obtained when the trial was commenced in July 1937, but it was considered that the number of sheep involved and the method of selection at that time gave sufficiently uniform groups in this respect.

The weights collected immediately after shearing, that is to say, after a period of fourteen months during which observations on strike were made, could only reveal the effects of certain strikes incurred during the course of the trial. It may be safely assumed that when a strike has been cured the animal tends to regain the weight it may have lost, the rate of the regain being to a large extent dependent on the food supplies available. During the progress of the trial at "Dungalear" there was a severe shortage of feed in the summer of 1937–1938 owing to lack of rain. Several graziers who saw the treated and control groups in February, 1938, remarked on the better condition of the treated sheep as a flock. By shearing time this difference was no longer apparent, as the pastures had improved, and, in addition, the incidence of strike had been low during the intervening period.

In considering the average body-weights, the data relating to the A, B, and C class sheep have been kept separate. The crude figures for the treated and the control sheep did not give a true picture of the loss resulting from fly-strike, as both struck and unstruck sheep occurred in each group. It was found that the average body-weight for the struck sheep in both the treated and control groups was the same, and the unstruck sheep in both groups were similarly comparable.

In the flock under investigation, there is a progressive decrease in weight with increase in "development," the mean body-weights of unstruck sheep in the three classes being 75 lb., 70 lb., and 68.5 lb. respectively. The greater weight of the unstruck A's compared with the unstruck B's and C's is statistically significant. The weights of the B and C class sheep were therefore re-arranged into two groups, one containing those of all the unstruck sheep and the other those of all the struck sheep. These are shown in Table 1.

It is suggested that the weights of the unstruck sheep shown in this table represent the maximum obtainable by the respective classes under the nutritional conditions prevailing, and those of the struck sheep show the effect of fly-strike in a flock where 100 per cent. have been struck. The mean body-weight of the control group, containing both struck and unstruck sheep, was found to be 67.5 lb.

Table 1.—Final Body-weight at Shearing of Sheep Struck and Unstruck During the Previous Period of Fourteen Months.

Classification.	Unstruck Sheep (Treated and Control).			Struck Sheep (Treated and Control).		
	Number Sheep.	Mean Weight.	Standard Error.	Number Sheep.	Mean Weight.	Standard Error.
		lb.	lb.		lb.	lb.
B Class	152	70·0*	± 0·68	49	66·5*	± 1·15
C Class	189	68·5*	± 0·65	186	63·5*	± 0·52
Total ..	341	69·2	± 0·47	235	64·0	± 0·48

* To nearest ½ lb.

The greater weight of the unstruck B's compared with the struck B's, and of the unstruck C's compared with the struck C's, is statistically significant.

The data relevant to the B and C class struck sheep were next divided into sub-groups, according to the number of occasions on which the sheep had been struck, and are set out in Table 2.

Table 2.—Effect on Body-weight at Shearing Time of Restrikes During the Previous Period of Fourteen Months.

Classification.	Unstruck.			Struck on 1 or 2 Occasions.		
	Number Sheep.	Mean* Weight.	Standard Error.	Number Sheep.	Mean* Weight.	Standard Error.
		lb.	lb.		lb.	lb.
B Class	152	70·0	± 0·68	36	67·5	± 1·31
C Class	188	68·5	± 0·65	94	64·5	± 0·65

Classification.	Struck on 3 or 4 Occasions.			Struck on 5 or More Occasions.		
	Number Sheep.	Mean* Weight.	Standard Error.	Number Sheep.	Mean* Weight.	Standard Error.
		lb.	lb.		lb.	lb.
B Class	13	63·5	± 2·22	..	..	..
C Class	46	64·0	± 1·24	46	60·0	± 0·93

* Weights to nearest ½ lb.

The actual number of B class sheep struck is small, but there is the same sort of progressive decline in body-weight with the increasing number of strikes as in C class sheep. The weight of the unstruck B's is significantly greater than that of the B class sheep which were struck on 3 or more occasions. The weight of the unstruck C's is significantly greater than that of C class sheep struck on 1 to 4 occasions, and the latter sheep are significantly heavier than those struck on 5 or more occasions.

From an analysis of the strike records of the individual sheep comprising the sub-groups in Table 2, it seemed that the size or severity of the strike was the main factor responsible for loss of body-weight.

The average body-weight of the small groups of sheep which had suffered from mild localized strikes only, even though they were struck on numerous occasions, did not differ markedly from that of the unstruck sheep. Unfortunately, the number of sheep falling within this category was too small for the groups to be treated statistically.

The association of size of strike with conformation has been noted by Carter and Belschner (1937) who, working with A and C class sheep only, found that the strikes in the C class tended to be the more extensive. At "Dungalear" 25 per cent. of the strikes in the B class and 40 per cent. of those in the C class were large. This observation may be regarded as confirming those of Carter and Belschner. Insufficient strikes occurred among A class sheep to enable a comparison.

3. Observations on Fleece-weight.

The wool returned by struck sheep may be depleted in two ways. Wool may be lost in the paddock, due to the sheep having been dressed or, in more extreme cases, to the shedding of the fleece. Secondly, the return may be further diminished by a temporary cessation or diminution of wool growth, owing to the constitutional disturbance associated with strike. At "Dungalear," two sheep, only one of which had been struck, shed their wool in the paddock.

One of the claims advanced by those advocating Mules' operation is that by controlling fly-strike a decrease in wool production is prevented. The extent of this saving is obviously limited by the fact that the operation cannot prevent all types of strike, and, further, by the fact that only a variable proportion of any untreated flock is struck. If fly-strike is absent, or mainly confined to body-strike, one would not expect any increase in wool production to result from the operation. It may be, however, that even if no fly-strike occurs the sheep may benefit from the removal of the urine-scalded skin of the medial breech folds.

In Table 3 is shown the mean greasy wool production of the treated and control sheep subdivided into A, B, and C classes.

TABLE 3.—EFFECT OF MULES' OPERATION ON WOOL PRODUCTION.

Classification.	Treated Group.				Control Group.			
	Number Sheep.	Sheep Struck.	Mean Wool Weight.	Standard Error.	Number Sheep.	Sheep Struck.	Mean Wool Weight.	Standard Error.
			lb. oz.	lb.			lb. oz.	lb.
A Class ..	19	..	11 9	± 0·38	19	..	11 8	± 0·37
B Class ..	101	9	11 14	± 0·15	101	41	11 8	± 0·14
C Class ..	188	45	12 2	± 0·11	185	138	11 12	± 0·12
Total ..	308	54	12 0	± 0·09	305	179	11 11	± 0·09

The greater mean greasy wool-weight of the treated group is statistically significant. However, in the groups listed in Table 3, a number of strikes occurred among the treated sheep, and a number of unstruck sheep were present in the control group. This table, therefore, shows the increased greasy wool production resulting from the operation *in this flock, under conditions pertaining during the experiment.*

In Table 4, the unstruck sheep from both groups are compared with the struck sheep from both groups.

TABLE 4.—EFFECT OF FLY-STRIKE ON WOOL PRODUCTION

Classification.	Unstruck Sheep.			Struck Sheep.		
	Number Sheep.	Mean Weight.	Standard Error.	Number Sheep.	Mean Weight.	Standard Error.
		lb. oz.	lb.		lb. oz.	lb.
A Class	38	11 9	± 0·26	..	..	..
B Class	152	11 13	± 0·12	50	11 3	± 0·20
C Class	189	12 4	± 0·12	184	11 10	± 0·11
Total ..	379	12 0	± 0·08	234	11 8	± 0·10

It will be noticed that the mean wool production per head among the unstruck sheep (Table 4) is the same as that for the treated group (Table 3).

If we consider the unstruck group as representing the potential wool production of the flock, and the control group (Table 3) as representing the flock production in the presence of the usual fly-strike incidence, it will be seen that during the fourteen months for which the trial lasted, fly-strike caused a loss of 5 oz. of wool per head, or approximately 2.5 per cent. of the wool produced.

At first sight this does not seem large, but it must be realized that it represents a loss of £16 per 1,000 sheep when greasy wool is worth 1s. per lb.

The wool production per head in this calculation is not materially affected by wool lost when struck sheep are dressed in the paddock, since only two strikes occurred among the control sheep between the last general crutching in June and the August shearing.

The loss resulting from fly-strike is more clearly shown by the weight of greasy wool cut from the B and C class sheep which had not been struck, or had been struck on one or more occasions. This is shown in Table 5.

TABLE 5.—EFFECT OF RESTRIKE ON WOOL PRODUCTION.

Classification.	Unstruck.			Struck on 1 or 2 Occasions.		
	Number Sheep.	Mean Weight.	Standard Error.	Number Sheep.	Mean Weight.	Standard Error.
		lb. oz.	lb.		lb. oz.	lb.
Class B	152	11 13	± 0·12	37	11 4	± 0·23
Class C	189	12 4	± 0·12	92	11 13	± 0·15

Classification.	Struck on 3 or 4 Occasions.			Struck on 5 or More Occasions.		
	Number Sheep.	Mean Weight.	Standard Error.	Number Sheep.	Mean Weight.	Standard Error.
		lb. oz.	lb.		lb. oz.	lb.
Class B	13	11 0	± 0·43	..	..	..
Class C	46	11 9	± 0·23	46	11 4	± 0·24

Consideration was next given to the effect of size of strike on wool production. Unfortunately, we can only record small numbers of sheep in the different groups, owing to the large variety of strikes which occurred. In Table 6 small strikes are considered to be those of from 1 inch to 2 inches in diameter, medium strikes 3 inches to 5 inches in diameter, and large strikes 5 inches or more in diameter. The data were grouped to show those sheep which incurred one small strike, those which had from 2 to 4 small strikes, those which had a single medium strike, and those which had a single large strike.

TABLE 6.—COMPARISON OF THE EFFECT OF STRIKES OF DIFFERENT SIZE ON WOOL PRODUCTION OF C CLASS SHEEP.

—	Unstruck.	One Small Strike.	Two to Four Small Strikes.	One Medium Strike.	One Large Strike.
Number of sheep	190	27	18	16	15
Average greasy wool weight ..	lb. oz. 12 4	lb. oz. 12 0	lb. oz. 12 0	lb. oz. 11 11	lb. oz 11 6.

Although the number of sheep available for inclusion in these groups was rather small, the results serve to show that in most cases small strikes, even when they are repeated, do not have as serious an effect as a single large strike. This is important from the point of view of jetting as a method of protection against strike, since it is claimed that jetting prevents strikes from spreading for a considerable period. In view of the results outlined in Table 6, this would be about as effective as complete protection so far as wool production is concerned.

4. Observations on Tender Wool.

Mackerras (1936) says: "The third type of break occurs in the general body of the fleece and may be extensive or patchy, severe or no more than a slight tenderness. It is due to the constitutional disturbance that accompanies anything more than a small strike." Belschner (1937) says: "It is well known that a 'break' in the wool occurs not infrequently following severe fly-strike and constitutional reaction of the animal."

An attempt was made to obtain some information on this point at "Dungalear," but unfortunately the extremely adverse pastoral conditions during the summer had obscured the position. The classer examined the fleeces for tenderness at two or three points along the side, using the normal trade method of determining a tender wool. This is done by stretching the staples taut and flipping them hard with the finger. Of the fleeces which were tender, 61 per cent. were tender one-third of the length of the staple from the skin surface.

Table 7 shows the percentage of tender fleeces among the struck and unstruck sheep.

TABLE 7.—ASSOCIATION OF STRIKE WITH TENDER WOOL.

Class.	Number of Sheep.	Number of Tender Fleeces.	Percentage Tender Fleeces.
A. Unstruck	39	5	13
B. Unstruck	152	12	8
B. Struck	50	3	6
C. Unstruck	190	23	12
C. Struck	183	50	27

In the above table the group of C class struck sheep is the only one to show a significant increase in the percentage of tender fleeces. The comparatively high percentage of tender fleeces in the unstruck portion of the flock, irrespective of the degree of "development," was probably due to the abnormally dry period and consequent changes in feed conditions during the late summer.

In order to determine the effect of the size of strikes on the occurrence of tender wool, the data relating to the struck sheep in C class were grouped into those from sheep which had incurred only small or medium strikes (up to 5 inches in diameter) and those from sheep which had large strikes (over 5 inches in diameter). This grouping is shown in Table 8.

TABLE 8.—ASSOCIATION OF SIZE OF STRIKE WITH TENDER WOOL.

——	Number of Sheep Struck.	Percentage Sound.	Percentage Tender.
Small or medium strikes only ..	111	85	15
At least one large strike	75	56	44

It will be seen from this table that the percentage of tender fleeces in the group which had small or medium strikes was approximately the same as for the unstruck C class sheep (see Table 7). There was a threefold increase in the percentage of tender fleeces in the group which had large strikes, irrespective of whether they had incurred one or more such strikes.

Nevertheless, even among these sheep, 56 per cent. of the fleeces were sound from a commercial point of view. In this connexion it is of interest to quote the specific cases of the four most heavily struck sheep in the experiment. Three of them had sound fleeces in spite of the fact that one was struck on seventeen occasions, including five large strikes, the second on seventeen occasions, with one large strike, and the third had thirteen strikes, three of which were extensive. The fourth, struck on fourteen occasions, including four large strikes, had a tender fleece. It would seem from this that tenderness of the wool, resulting from strike, is dependent on the degree of constitutional disturbance involved, and that, while such disturbances are more likely to result from an extensive strike than from smaller ones, it is only in some of the large

strikes that the resulting disturbance is sufficient to cause a readily detectable degree of tenderness in the wool.

An attempt was made to estimate the approximate date at which tenderness occurred on the basis of its position on the wool fibres. In this way it was hoped to judge whether the tenderness in the severely struck sheep bore any relation to the date of the strike, and that of unstruck sheep to the period of feed shortage. The estimations, however could not be made with sufficient accuracy for this purpose.

5. Conformation and Fleece Characteristics.

It has been shown that by using the Mules' technique of removing wrinkles, the incidence of breech-strike can be greatly reduced. An alternative method is to breed plain-breeched sheep. The argument usually advanced by those who oppose this latter plan is that the plain type of sheep does not cut such a heavy fleece, especially under the grazing conditions of north-western New South Wales and southern and central Queensland, where the incidence of fly-strike is high. Unfortunately, very few figures are available to show the comparative wool production of plain and wrinkly flocks under these conditions. It is generally considered, however, that the plain sheep tends to produce a somewhat more uniform fleece of slightly higher yielding wool than the wrinkly sheep, but that the wool fibres are longer and "stronger" and the fleece is less dense.

At "Dungalear," an opportunity occurred to collect further information on these points. As the sheep belonged to the stud, their parents had been culled to a relatively uniform type for body conformation and fleece characteristics. This limited the selections we were able to make, and accounts, to a certain extent, for the uniformity in the wool types in the different classes. It should be realized that the A, B, and C class sheep do not represent homozygous types, but are individual variations in a heterozygous flock.

Belschner, Carter, and Turner (1937) investigated the wool production of plain and wrinkly sheep in a similar type of flock, but without differentiating between struck and unstruck sheep. They concluded that the C class sheep cut approximately 5 oz. more wool per head than the A class sheep. It will be observed that their figure is very close to that which obtained for similar classes of sheep in the control group at "Dungalear," namely, 4 oz.

In Table 9 (regrouped from Tables 3 and 4) the greasy wool weights of the unstruck A, B, and C class sheep are given, together with the wool weights of the control sheep (struck and unstruck).

Table 9.—Comparison of Greasy Wool Production of Unstruck Sheep and Control Group.

Classification.	Unstruck Sheep from Both Treated and Control Groups.			Control Group, including Struck and Unstruck Sheep.		
	Number Sheep.	Mean Weight.	Standard Error.	Number Sheep.	Mean Weight.	Standard Error.
		lb. oz.	lb.		lb. oz.	lb.
A Class	38	11 9	± 0·26	19	11 8	± 0·37
B Class	152	11 13	± 0·12	101	11 8	± 0·14
C Class	189	12 4	± 0·12	185	11 12	± 0·12

In the unstruck sheep it is seen that the C class sheep cut 11 oz. per head, and the B class sheep 4 oz. per head, more than the A class sheep. If, however, the normal rate of fly-strike is taken into account and the control groups are considered, it will be seen that the advantage of the C class sheep is reduced to 4 oz. while the B class sheep now show no advantage. In designing any experiment to test the relative potentialities of plain and wrinkly sheep it is therefore essential to eliminate fly-strike from the experimental groups.

As each fleece was classed, the spinning count, staple length, and clean scoured yield were estimated.

Figs. 1, 2, and 3 show the results so far as the unstruck sheep are concerned, set out in the form of dispersion curves. The number of sheep involved in these observations was 379, comprising 38 A's, 152 B's, and 189 C's, and it must be borne in mind that the flock has

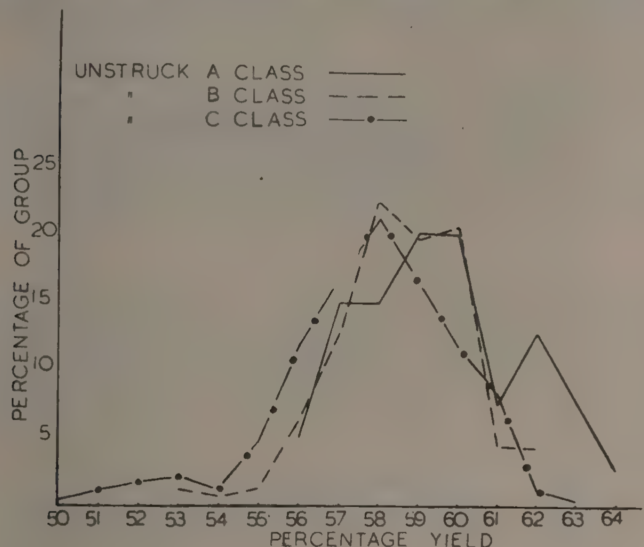

FIG. 1.

been selected for a number of generations to conform to a certain type. It is clearly seen that while, in general, the wool of the A, B, and C class sheep was strikingly similar in these three respects, the same slight tendency is present as has been observed by other workers, namely, for the A class sheep to have longer, "stronger," and higher yielding wools, while the C class sheep tend to have shorter, finer, and lower yielding wools, the B class sheep being intermediate but approaching more nearly to C class than to A class.

6. Conclusions.

1. Breech-strike resulted in loss of body weight in young sheep, the extent of the loss depending on the number and size of the strikes.

2. Evidence is advanced to show that what may be regarded as the average breech-strike incidence in a flock of this type caused a loss in

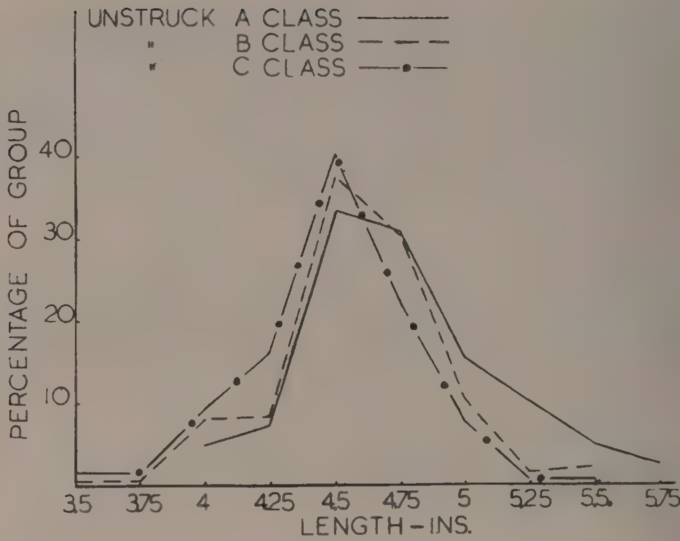
UNSTRUCK A CLASS
" B CLASS
" C CLASS
PERCENTAGE OF GROUP
40
30
20
10
3.5
3.75
4
4.25
4.5
4.75
5
5.25
5.5
5.75
LENGTH-INS.

Fig. 2.

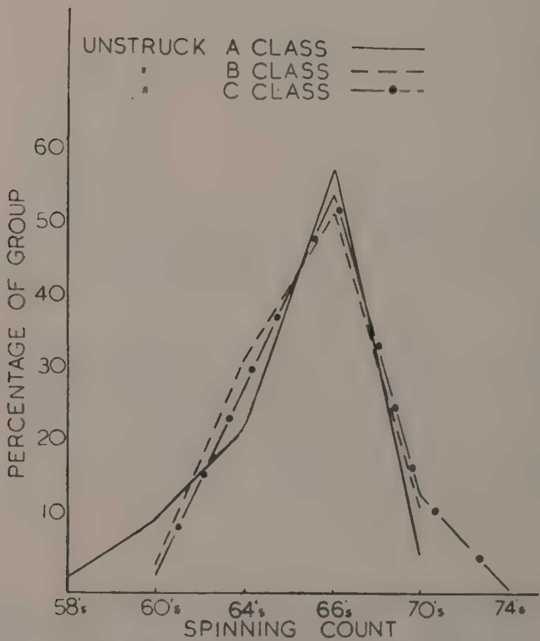
UNSTRUCK A CLASS
" B CLASS
" C CLASS
PERCENTAGE OF GROUP
60
50
40
30
20
10
58's
60's
64's
66's
70's
74's
SPINNING COUNT

Fig. 3.

wool production of 5 oz. per head or approximately 2.5 per cent., equivalent to £16 per 1,000 sheep with greasy wool at 1s. per lb. This loss results from the effect of strike upon wool growth, and in estimating the economic loss due to fly-strike it must be added to the value of sheep dying, the value of wool removed and lost when strikes are dressed in the paddock, and to the cost of labour and of strike dressings.

3. There appeared to be a relationship between fly-strike and "tenderness" of the fleece only in the case of extensive strikes, and even in such cases over 50 per cent. of the sheep produced sound wool.

4. The unstruck C class sheep produced 11 oz. per head, and the unstruck B class sheep 4 oz. per head, more greasy wool than the unstruck A class sheep. When the control group is considered, however, that is to say, the group which incurred the usual rate of fly-strike for this flock, the C class sheep, of which many were struck, produced only 4 oz. per head more than the A class; and the B class sheep, among which also there were many strikes, produced the same amount of greasy wool per head as the A class.

5. The wool produced by the A class sheep tended to be slightly longer and "stronger" than that of the B's or C's and to give a slightly higher estimated yield of clean scoured wool.

6. When considering the inherent merits of A, B, and C class sheep as wool producers, it is essential to eliminate, or discount, the effects of fly-strike and to take into account the clean scoured yield of the fleeces.

7. Acknowledgments.

We would like to express our thanks to Mr. R. Minter who assessed the various wool characters for us, and to Miss M. Hornby who has examined out data statistically. We must again thank the manager of "Dungalear" Station, Mr. Makeig, and his staff, especially Mr. J. C. Stephen, for the assistance and facilities which made these observations possible.

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Foot-rot in Sheep: A Progress Report on Field Trials.

*By T. S. Gregory, B.V.Sc., Dip. Bact.**

Summary.

1. In the past it has been a common belief that foot-rot in sheep will occur in certain districts when environmental conditions, such as sufficient rainfall and improved pastures, are present, but the discovery by Beveridge of a causal organism has led us to believe that all such environmental conditions are merely contributory factors. Field trials are described which were planned to test the accuracy of these theories and to estimate the time of survival of the contagium of foot-rot under conditions of practical farming.

2. The results of these field trials have invariably led to the conclusion that the presence of a specific organism is essential, and that, in its absence, foot-rot will not develop in healthy sheep when they are placed in the most favorable environmental conditions.

3. The trials indicate that the causal organism will not usually survive for more than seven days on contaminated pastures, when the seasonal conditions usually met with in Australia are most favorable. It is probable that sheep yards, stock routes, &c., would be adequately decontaminated at the end of a similar period.

4. It is considered that, after allowing for a reasonable margin of safety, a spelling period of fourteen days for the effective decontamination of pastures under Australian conditions can be recommended.

Introduction.

Investigations concerning the viability of the contagium of foot-rot, and the methods for the control of the disease in the field which were based thereon, have already been described by Beveridge (1938)†. At the same time he published an account of subsequent work which resulted in the isolation of a micro-organism (organism "K") which he considered to be the probable causal agent of foot-rot. His own later observations (unpublished) have confirmed him in that view, and all experimental work conducted by this Division indicates that this organism is the essential cause of the disease. In field experiments, such as those to be described, it has always been possible to correlate the development of clinical symptoms of foot-rot with the presence of the organism "K," and many investigations have failed to reveal any other habitat.

The opinion that foot-rot is a disease that develops more or less spontaneously among sheep depastured in certain districts, or on certain properties, when seasonal conditions are favorable, has been held for so long in this and other countries that properly planned field trials appeared to be the best method of producing evidence by which its accuracy could be tested. The first four trials described hereunder were planned accordingly.

Regarding the viability of the contagium of foot-rot, the experiments of Beveridge (*loc. cit.*) indicated that material from lesions, whether kept moist or air-dried, remained infective for not more than four days, and when mixed with mud usually for three days, but rarely

* An officer of the Council's McMaster Animal Health Laboratory, Sydney.

† Beveridge, W. I. B. (1938).—*J. Coun. Sci. Ind. Res.* (Aust.), **11**: 1, 4, and 14.

for one week. By placing healthy sheep in muddy yards, which were contaminated by infected sheep and then spelled for different periods, the survival of the organism was indicated after a period of 24 hours in one out of three experiments, but in experiments of a similar type using damp pasture, no infection was produced in healthy sheep grazed thereon after spelling periods as short as nine hours. The results (to be published) of other experiments carried out by ourselves show, however, that infection can take place when healthy animals are moved on successive days through a series of muddy yards which have been spelled for five days after being very heavily contaminated. No infection was produced after spelling periods of seven days.

Such evidence is of interest in indicating the possible length of survival under specially favorable conditions with intensified contamination, and it served as a basis for the planning of field trials Nos. 5 and 6.

Attention has already been drawn to the necessity for carefully specifying the condition described as "foot-rot"; and the differential diagnosis of foot-rot from other infective processes which involve the foot, and which occur in Australia, has also been discussed (Gregory, 1939)*. In the present paper it should be understood that we refer to what is generally known as contagious foot-rot, which we define as a specific infectious disease due to the activities of the organism "K" and naturally transmitted to healthy sheep through the agency of diseased sheep, when the environmental conditions favour the contamination of pastures and the survival of the organism "K" thereon.

Trial No. 1.

The initiation of this trial was described by Beveridge (1938), and its progress after ten months was also reported by him. It is a trial which has been conducted on portion of the irrigated pastures of the State Research Farm at Werribee, Victoria. This portion was spelled for a period of two weeks, then stocked with 200 sheep free from foot-rot.

At infrequent intervals they were taken out of the spelled paddock for routine procedures such as shearing, dipping, &c., and when returned they were walked through a bath of antiseptic as they re-entered the paddock. During the period from March, 1937, to December, 1938, when they were transferred to another paddock, they remained free from foot-rot although they were grazing on highly improved pastures composed of a mixture of clovers and grasses, at a very high rate of stocking and under seasonal conditions which favoured the persistence and spread of foot-rot among sheep on other parts of the same property. Moreover, the lambs to which they gave birth in 1937 and 1938 remained free from foot-rot. This latter fact removes the possibility of the operation of any special immunity factor, for, while such a factor might be considered remotely possible in the case of the ewes, it is well known that young lambs are highly susceptible to this disease.

Conclusions.

1. If a contaminated, irrigated pasture is kept free from sheep for a period of two weeks, then sheep which are free from foot-rot may subsequently be grazed thereon without developing the disease.

* Gregory, T. S. (1939).—*Aust. Vet. J.*, 15: 160.

2. Sheep which are free from foot-rot may graze on decontaminated pastures without developing the disease provided that care is taken to prevent the introduction of the causal organism by infected sheep.

3. Neither the richness of the soil or pastures nor the combination of environmental conditions such as plentiful soil moisture and suitable temperatures, which favour the spread of foot-rot, are able to produce the disease in the absence of the causal organism "K."

Trial No. 2.

This has been conducted in the Western District of Victoria, on a property specially chosen by the Veterinary Officer of the Research Association in that district because of the history over a period of very many years of continued foot-rot infection in sheep depastured thereon. The infection rate had been so heavy that it was a generally stated opinion that foot-rot would develop in any flock of sheep introduced there. In other words, it was considered that the favorable environmental conditions on that property when the soil was wet would invariably lead to an outbreak of foot-rot among any sheep grazing upon it.

The trial was commenced in mid January, 1938, when inspection of the sheep on this property showed that even in the summer a number of obviously lame sheep could be detected. Examination showed these to be of the "carrier" type, with small foci of infection under the horn of the hoof.

The procedure adopted in this trial was as follows:—

1. In a paddock of about 170 acres, an area of approximately 15 acres was fenced off so as to include typical pasture, a dam with a muddy bank, and portion of a small pine plantation, all of which were features of the property which were considered to provide a suitable environment for the initiation of infection.

2. All the lame sheep in the 170-acre paddock were crowded on the 15-acre "test paddock" and allowed to remain for a fortnight in order to increase the contamination of the pasture. (This, however, would not be extensive, as the "test paddock" at that time was dry except for the muddy edge of the small dam.)

3. They were then removed from the "test paddock" and again depastured on the surrounding area. The "test paddock" was then kept free from sheep for a period of six weeks.

4. After this period had elapsed, 73 crossbred wether weaners were transported by motor truck from a property free from foot-rot, and 50 were placed in the spelled "test paddock." All feet of these sheep were carefully inspected and were found to be free from foot-rot; as an extra precaution they were transferred from the motor truck to the "test paddock" through a foot-bath of bluestone solution. The remaining 23 sheep were similarly treated but were placed outside the "test paddock," so that they would be grazing with the original infected flock on pasture that would presumably be contaminated. The 23 sheep of this latter group were to act as controls with the object of demonstrating the susceptibility to foot-rot of the clean sheep introduced into the experiment.

Results.

As the autumn remained unusually dry, the conditions for the first few weeks were not favorable for the spread of foot-rot. At the end of May, however, the infection became more active amongst old infected cases and began to spread to other sheep. During the month of June there were 21 wet days, and 4 inches of rain fell. It was then reported that about 20 per cent. of the sheep on this area had become lame with foot-rot. At mid-July some of the "control" weaners were reported to be affected with foot-rot, and some smears forwarded to the laboratory showed, by microscopical examination, the presence of the organism "K" as well as spirochaetes and other bacteria commonly found in typical cases. We inspected the control group personally at the beginning of September, and at that time six of the 23 appeared clinically to be affected with typical foot-rot, and the diagnosis was confirmed by microscopical examination of smears of material taken from the lesions. It was considered that such a result adequately proved the susceptibility to foot-rot of the clean sheep introduced into the experiment, and, as the owner was desirous of preventing further infection in the control group, they were removed from the experiment for treatment.

During the time that had elapsed since the commencement of the trial, the 50 sheep in the "test paddock" were separated only by a wire fence from the surrounding contaminated paddock containing infected sheep. They were constantly observed by the District Veterinary Research Officer and less frequently by ourselves, but foot-rot was never detected. Moreover, they have now remained in the same paddock for a period of eighteen months, covering the rainy months of two successive years, and have remained free from infection. During the wetter periods of both of these years the seasonal conditions favoured the development of foot-rot on other parts of this property and on other properties in the district.

Conclusions.

1. The results of this test in a dry farming district confirm conclusion No. 2 derived from the results of Trial No. 1, which was conducted on irrigation pastures.

2. The special selection of environmental conditions considered by many stock owners to be, of themselves, capable of causing foot-rot, fails to produce the disease in unaffected sheep if they are not in contact with infected sheep or recently contaminated pastures.

Trial No. 3.

In the same district of Victoria as that referred to in Trial No. 2, observations have been made, on three properties, of the degree of success attending the application of methods for the control of foot-rot that were suggested by Beveridge (1938). These properties normally carry twelve, fourteen, and thirty thousand sheep respectively. During the four or five years preceding the commencement of the trial, foot-rot had been prevalent in the wet periods of each year, when 10 to 15 per cent. of the flock were often lame at any one time; lambs commonly became affected. The figure for the average annual rainfall on these properties is between 22 and 24 inches.

Result.

Complete success has followed the attempts at eradication. The work was aided by prolonged dry periods in two successive years, but the final elimination of a few persistent "carriers" by slaughter left these properties free from infection. During the current year no case has been detected.

Conclusions.

Foot-rot can be eradicated during the drier months by adequate curative treatment or elimination of all "carriers." It will not re-appear if care is taken to prevent the re-introduction of affected sheep.

Trial No. 4.

This was similar in nature to Trial No. 3 but was conducted in southern New South Wales. The last case of suspected contagious foot-rot on this property, which carries 11,000 sheep, was eliminated in July, 1937, and from that time until the autumn of 1939 the rainfall was so low and the pastures so dry that foot-rot seemed to have disappeared from all that portion of the State. There was, in fact, during this time of drought, too little moisture to allow of the development of active lesions in "carriers," with the consequent spread of the disease. In the autumn of 1939 the rainfall was excessive, an amount equal to the annual average being received over a period of eight weeks. The long period of freedom from lameness in sheep ceased abruptly, and it was soon apparent that there was a widespread occurrence of a condition for which the names of "digital suppuration" or "foot-abscess" have been suggested (Gregory, 1939, *l.c.*). This type of lameness may be distinguished from foot-rot, firstly, by the fact that generally only one claw of a lame sheep is affected; secondly, because there is a definite accumulation of pus under the horn of the claw or in the tissues round the coronet; and, thirdly, because older sheep are more commonly affected than younger sheep. These three points provide a direct contrast to the clinical findings in foot-rot. Moreover, the organism "K" is found only in cases of true foot-rot.

It may be briefly stated that some of the sheep on this trial property suffered from lameness due to "foot-abscess" which was prevalent throughout the district. Evidence has already been produced by Gregory (1939) to show that this condition is caused by the pyogenic activity of microbes normally present in the intestines and faeces of sheep, so that prevention by elimination of the causal organisms has not been possible. The property in the trial might therefore have been expected, in common with others in the district, to be affected by this type of lameness. Within a few weeks, however, it became apparent that on neighbouring properties from which "carriers" of foot-rot had not been eliminated during the drought, and on those where they had presumably been introduced, the environmental conditions were now proving suitable for the reactivation of foot-rot in "carriers" and the spread of the disease to other sheep of all ages which were in contact. After a lag period immediately following the commencement of autumn rains, this spreading movement gathered momentum.

On the trial property, where all affected sheep and "carriers" had been eliminated and no others introduced, there was a state of complete freedom from foot-rot. This state of freedom has now persisted throughout a period of six months up to the end of September, whereas, on neighbouring stations, large numbers of sheep and also newly-born lambs have become affected with the disease.

Results.

On a trial property situated in southern New South Wales, where all sheep affected with foot-rot had been eliminated previous to the breaking of a drought, foot-rot has not subsequently developed. It has been prevalent on neighbouring properties where eradication measures had not been in operation.

Conclusions.

1. As measures for the eradication of foot-rot have been successfully applied in widely separate areas, there is every reason to believe that general application would prove successful.

2. The same as conclusion No. 2 of Trial No. 1, which was also directly supported by the results of Trials No. 2 and 3.

Trial No. 5.

The object of this trial has been to determine, as accurately as possible, under practical conditions, the period during which pastures remain infective after sheep with active lesions of foot-rot are grazed thereon and then removed. The area selected was on the State Research Farm at Werribee, Victoria, where suitable improved pastures were made available for the experiment. Experiments with small moist plots, conducted at the McMaster Animal Health Laboratory at Sydney, had already indicated the probable time of survival of the causal organism "K," so that the field trial was planned as follows:—

1. A number of small plots of improved pasture, approximately $\frac{1}{4}$ acre in area, were fenced off in such a way that the dividing fences were placed along the tops of irrigation check banks. These banks prevented gross contamination of one pasture from another by surface drainage.

Boxes of lick were placed in each field to encourage the congregation of sheep at a fixed point so as to concentrate contamination thereabout.

2. Six sheep with active lesions of foot-rot were introduced to act as a "contaminating group." Throughout the course of the experiment they ensured the contamination of the pasture, as they provided each week an average number of approximately eighteen actively infected feet.

Two sheep free from foot-rot, chosen from the same mob as the "test group" which will next be described, were allowed to run with the "contaminating group." If these developed foot-rot it would show that the environmental conditions favoured the development of the disease in healthy sheep running with infected animals.

The six sheep of the "contaminating group" and the two controls were allowed to graze on each small field for seven days, being then transferred to the next field.

3. A "test group," containing five sheep similar to the two controls with the "contaminating group," were allowed to graze for successive periods of seven days on a series of pastures which had been contaminated for seven days by the "contaminating group" and then spelled for seven days.

If it be supposed that the maximum period of viability of the causal organism of foot-rot be seven days on such pastures, then it will be seen that maximum contamination will have taken place by the seventh day of grazing. At this time the organisms deposited on each successive day would still be viable. After a spelling period extending over the next seven days, they would all be dead and it should be perfectly safe to introduce healthy sheep.

The five sheep of the "test group" were introduced to test this theory, and the trial exposed them to possible infection in such a spelled paddock not on one occasion only but in six such spelled paddocks during the six successive weeks.

Results.

1. Each of the two healthy control sheep placed with the "contaminating group" developed foot-rot in three feet before the end of the third week. This showed that the environmental conditions in the experiment favoured the spread of the disease from the "contaminating group" to sheep grazing with them.

Moreover, as the two controls and the "test group" were selected at random from the same mob, it indicated that the "test group" should be equally susceptible to infection.

2. The "test group," which during six successive weeks was allowed to graze for seven-day periods on pastures contaminated for seven days then spelled for seven days, failed to develop the disease.

Conclusion.

Under practical field conditions of sheep grazing in this district, irrigated and improved pastures which have been heavily contaminated by sheep affected with foot-rot would be sufficiently decontaminated after a spelling period of seven days.

Trial No. 6.

This trial, conducted at Werribee, was similar in plan to the last, except that the periods allowed for contamination, spelling, and grazing of test sheep were each of five days. The same contaminating group of sheep was used and approximately the same degree of infection was maintained in them. No sheep were run with them to test the suitability of environmental conditions for the transfer of infection, but this was indicated by the continued activity of the lesions in the infected sheep. Controls to indicate the susceptibility of the sheep of the new test group were unnecessary as the latter were selected from the same mob as those in Trial No. 5.

In this trial the test sheep were grazed on eleven spelled paddocks for five-day periods over a total period of fifty-five consecutive days.

Results.

None of the animals of the test group developed foot-rot.

Conclusions.

1. Under practical conditions of grazing, with plentiful green feed and moist soil, a spelling period of only five days was sufficient to bring about effective decontamination of pastures.

2. It is probable that contaminated and moist yards, stock routes, &c., will often fail to cause infection with foot-rot after a spelling period of only five days.

General Conclusions and Discussion.

In a previous article (Gregory, 1939) it has been pointed out that in Australia and other countries many factors have contributed to the uncertainty regarding the nature and classification of diseases affecting the feet of sheep. Consequently, there have been no well founded plans for the adequate control or eradication of the contagious type of foot-rot. The work of Beveridge has, however, led to a marked clarification of our views, and it was deemed advisable to test further, under field conditions, his conclusions regarding the role played by the organism " K " and the methods of control and eradication which were based thereon.

It is now our considered opinion, as the result of these trials, that the presence of the organism " K " is indeed essential for the production of the symptoms typical of foot-rot. Moreover, we consider that the trials which have been conducted in three separate districts and in two States have provided very weighty evidence in support of the theory that the organism " K " is not normally found in the environment of the sheep, but is present under practical conditions of sheep farming in this country only if it is introduced by infected sheep.* In the trials it has been shown that the disease disappeared when all infected sheep were cured or removed from flocks.

Further verification should be obtainable from the observations of other veterinarians in the field, and we have already had a number of favourable reports from three Australian States. In some cases, conclusions were drawn from field manipulations of sheep which simulated closely the essential points of our trial protocols, and there was no doubt on the part of the observers regarding the results of spelling infected pastures. No spelling period of less than a fortnight had been tested.

When field observations are undertaken it is especially necessary to note that, although he may state that no sheep are purchased and introduced on to his property, an owner may forget the introduction of rams. The latter are very susceptible to foot-rot and commonly act as "carriers."

Regarding the maximum period of viability of the contagium of foot-rot on pastures, yards, &c., it is not possible to specify this precisely. It will vary according to the season of the year with factors such as soil temperatures and soil moisture. It seems probable that under the

* Goats may become affected with foot-rot and, in some countries, would have to be considered as likely carriers.

most favourable conditions for its survival which are likely to be encountered in the Commonwealth of Australia, or in any temperate climate, the period would be approximately seven days. In drier months of the year it would be considerably less.

We consider, therefore, as the result of our experiments, that in districts in Australia where foot-rot occurs, seven days would prove a safe spelling period. It would be wise, however, to allow a margin of safety such as a further seven days in ordinary circumstances and, consequently, a spelling period of fourteen days is recommended at those times of the year when environmental conditions are most favourable to the survival of the causal organism and the spread of the disease.

Acknowledgments.

We wish to make grateful acknowledgment of the help and co-operation afforded by the Western District Research Association of Victoria, its Veterinary Research Officer, Dr. W. Carr-Fraser, and the individual members on whose properties some of these trials were conducted. Our thanks are due also to Mr. H. A. Mullett, Director of Agriculture, Victoria, and to Mr. Wilson, Manager of the State Research Farm, Werribee, for the facilities afforded there, and to the Senior Irrigation Officer, Mr. T. E. Beruldsen, and his colleagues, not only for controlling trials, but also for their interest in the work and their careful attention to every detail.

Regarding the trial conducted in New South Wales, we wish to express our thorough appreciation of the manner in which the owner and manager of the property concerned granted all necessary facilities. Their appreciation of the results of the experiment, whereby the property was rendered free from infection, has been an encouragement to our work.

Acknowledgment is also due to the Australian Wool Board for a contribution toward the cost of foot-rot investigations.

Method for Obtaining Eggs and Larvae of *Nematodirus* Spp. for Experimental Purposes.

*By G. P. Kauzal, D.V.Sc.**

Summary.

1. A technique is described which is suitable for collection of eggs of *Nematodirus* for experimental purposes.

2. The method used is an adaptation of Sheather's well-known sugar flotation technique.

3. Continuous supplies of infective larvae of *Nematodirus* can be procured, free from other living nematode larvae, without much effort.

A method is here described by which it is possible to collect suitable, uncontaminated, infective material (eggs and eventually infective larvae) of *Nematodirus* spp. from the faeces of sheep which are harbouring several species of nematodes. It has been developed to facilitate a continuous supply of mature larvae for the purpose of studying the pathogenic effect of this species and in principle is a modified sugar-flotation technique, adapted to deal with large quantities of faeces from which the eggs of *Nematodirus* are to be separated.

Sheather (1924)† described and was the first to recommend the use of sugar solution as a means of separating nematode eggs from faeces. In the course of his experiments he found that, while it is an advantage, from the point of view of speed, to use the centrifuge, a reasonable number of eggs can be recovered without centrifuging the preparation. It is thus possible for the technique to be adapted for the special purpose just mentioned. Centrifuging the large quantities of faecal suspension required would have been impracticable and tedious in comparison with the method described hereunder.

The procedure followed by the author is as follows:—

1. The faeces are collected over a period of 24 to 48 hours in bags tied to a sheep (preferably a wether) which has been shown to be infected with *Nematodirus*.

3. The fine suspension of faeces in water is then passed through for about 24 hours and the pellets are then broken up to form a fine suspension. It has been found most convenient to use a wide-mouthed jar as this enables one to break up the pellets easily by hand, using surgical gloves.

3. The fine suspension of faeces in water is then passed through a sieve having 30 meshes to the linear inch, and the rough filtrate is distributed in one-litre quantities in a series of two-litre Erlenmeyer flasks. Each flask is then filled up with saturated sugar solution.

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* An officer of the Council's McMaster Animal Health Laboratory, Sydney.

† Sheather, H. L. (1924).—*Vet. Rec.*, 4 (26): 553-557.

4. The mixture of faecal filtrate and sugar solution is thoroughly mixed and the flasks are set aside for 24 hours, during which period the majority of the nematode eggs will rise into the upper 150-200 ml. of the liquid.

5. The upper 150 ml., or thereabouts, is next decanted by a quick pouring movement from each flask into a container of about one gallon capacity. (The author has found a cylindrical glass specimen jar measuring about 15 inches by 6 inches to be most convenient.)

At this stage the mixed nematode eggs are contained in a relatively small volume of water containing sugar and faecal matter, and the subsequent processes are for the purpose of removing these.

6. Fill the container mentioned in (5) with tap water. This is best done by a forceful stream of water directed onto the bottom of the container through rubber tubing connected to a tap, as thorough mixing is thereby ensured. The container is then set aside for 24 hours during which the nematode eggs and the heavier faecal debris settle to the bottom.

7. Syphon off the supernatant liquid to near the level of the sediment. The remaining fluid and sediment together are then placed in a series of conical centrifuge tubes which are allowed to stand for a further two hours. During this time the *Nematodirus* eggs, which are larger and heavier than those of *Haemonchus* and *Trichostrongylus,* settle first, and fairly quickly, so that they may be seen as a whitish mass at the bottom of the tubes. Above them is a sediment composed mainly of faecal material and the lighter nematode eggs. If the tube is now carefully inverted, the liquid and the upper sediment can be poured off leaving a small sediment which is rich in nematode eggs, most of which are those of *Nematodirus* spp.

8. Refill the tubes with water, shake and, after allowing to settle for a further two hours, again pour off the supernatant fluid and the upper portion of the sediment. This operation is repeated three or four times till the remaining eggs are suspended in relatively clear water.

9. Finally the eggs are shaken up with water and the resulting suspension is set out in shallow petri dishes to a depth of 3 to 5 mm. These are maintained at 24° to 30° C., and the *Nematodirus* eggs develop to the infective larval stage in approximately fourteen days. Frequently, *Nematodirus* eggs containing fully developed larvae can be seen still unhatched after this period, and in such cases mechanical agitation will often induce hatching. It is not advisable to use unhatched larvae in pathogenicity or other trials as it is not yet known whether they can be relied upon to hatch out after ingestion.

The preparation obtained by stage (8) above will still contain a proportion of eggs from other species of nematodes which were present in the sheep which supplied the faecal sample, most commonly

Haemonchus and *Trichostrongylus*, but these will invariably degenerate after they reach the first larval stage. At this stage in their development these larvae must feed on faecal particles, bacteria, etc., if they are to survive, and the above process has removed their food supply. But *Nematodirus* spp. on the other hand, pass all the intermediate larval stages within the egg shell and thus develop normally in water without requiring food.

In addition to saturated sugar solution, other flotation solutions such as saturated sodium nitrate (Kalantarjan, 1938*) were tried but without success. It must be remembered that, whilst there may be several other diluents which would float the eggs of this species, it is essential that, apart from being able to float them, they must not affect their viability.

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* Kalantarjan, E. V. (1938).—*Med. Parasitol., Moscow*, 7 (1): 142-3.

Chemical Studies in Connexion with the Dosing of Sheep with Phenothiazine.

*By M. Lipson, B.Sc.**

1. A Method for the Purification of Commercial Phenothiazine.

Commercial phenothiazine contains other compounds besides pure thiodiphenylamine. Smith (1938) has reported that small quantities of a dark green, ether-insoluble compound are found in the commercial product but that little or no diphenylamine is present. Besides the major constituent, certain commercial preparations contain small amounts of a wetting agent, and about 2 per cent. beta naphthol may also be present as an anti-oxidant.

During chemical investigations on the use of phenothiazine as an anthelmintic, it was necessary to prepare samples of pure phenothiazine from the commercial product. A rapid and convenient method for doing this, using the well-known method of chromatographic adsorption such as has been described by Cook (1936) and Koschara (1937), has been evolved.

The commercial product (10 g.) is dissolved in boiling benzene (300 ml.) and then sucked slowly through an alumina column (length 16 cm., diameter 2 cm.) which has been previously wetted with the solvent. The column is then washed with another 100 ml. of hot solvent. A red solution containing the unadsorbed material passes through the column. Evaporation of this solution leaves a residue (7.9 g.) which consists of phenothiazine contaminated with small amounts of a red impurity. The latter can be removed in solution by powdering the residue and washing with hot petroleum ether (boiling range 60° to 80° C.) which leaves pure phenothiazine (6.7 g.) as a residue: melting point, 180° C.

At the top of the alumina column there was a dark green band which extended for one centimetre, and this was extracted with boiling acetone. The extract, when evaporated to dryness left a dark green residue (1.1 g.) which was insoluble in ether and so could be washed with this solvent.

This compound is probably identical with that detected by Smith (*loc. cit.*) in samples of commercial phenothiazine.

The red impurity in the filtrate is extremely soluble in most organic solvents but insoluble in water or sodium hydroxide solution. Consequently, it cannot be either phenothiazone or thionol, as the former is water-soluble and the latter is soluble in sodium hydroxide.

In purifying larger amounts of the commercial product, a modification of the above method has been adopted. Instead of passing through a column of alumina, the hot benzene solution of commercial phenothiazine is shaken with alumina and allowed to stand. The resulting red solution is filtered, evaporated to small bulk, and cooled. Petroleum ether is then added; it precipitates the phenothiazine: melting point, 178° to 180° C.

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2. The Quantitative Estimation of Phenothiazine in Sheep's Faeces.

Phenothiazine readily oxidizes, and this fact must be borne in mind in applying any method for recovering it quantitatively from biological material.

Known quantities of pure phenothiazine were added to 10-g. lots of sheep's faeces and each was thoroughly mixed. The samples were then dried in the oven for two hours. In order to recover the added phenothiazine from these samples the following solvents were tried: (1) benzene, (2) chloroform, (3) acetone, (4) alcohol. The amount of phenothiazine in the extracts was estimated by the colorimetric method described by Eddy and De Eds (1937); it depends upon the oxidation of phenothiazine in alcoholic solution with bromine water to a highly coloured red derivative. It has been found that any natural pigments extracted from the faeces by the solvents are decolourized by the bromine water used in the test and so do not affect the results. The estimation of the colour intensity was carried out by visual matching in a colorimeter.

Phenothiazine is extremely soluble in acetone, and it was thought that this solvent could be used to remove it quickly and conveniently from faeces.

In Table 1 is set out a summary of the results that were obtained using acetone as a solvent.

TABLE 1.—RECOVERY OF PHENOTHIAZINE FROM FAECES USING ACETONE.

Phenothiazine Added.	Phenothiazine Estimated.	Recovery Per cent.	Method.
mg.	mg.		
4.3	2.9	67	Washed with hot solvent
3.7	2.1	57	Washed with hot solvent
1.6	1.4	88	Washed with hot solvent
1.3	0.8	62	Washed with hot solvent
3.6	1.5	42	Soxhlet-extracted, two hours

These results indicate that, despite the extreme solubility of phenothiazine in acetone, this solvent did not recover this compound quantitatively from faeces.

Of the other solvents, alcohol gave the most consistent results, but in no instance was there a 100 per cent. recovery. The results obtained by Soxhlet-extracting overnight (17 hours) with alcohol are recorded in Table 2.

TABLE 2.—RECOVERY OF PHENOTHIAZINE FROM FAECES BY OVERNIGHT EXTRACTION WITH ALCOHOL.

Phenothiazine Added.	Phenothiazine Estimated.	Recovery Per cent.
mg.	mg.	
2.0	1.4	70
2.1	1.6	76
2.6	1.9	73
3.5	2.8	80
4.3	3.3	77
5.0	4.1	82
23.2	19.8	85
45.2	39.6	88

Alcoholic solutions containing known quantities of phenothiazine were next boiled under reflux for the same time period as in the above experiments, and the phenothiazine content of the solutions was then estimated. Using varying amounts of phenothiazine the average recovery was only 88 per cent., which indicated that decomposition had occurred during boiling accounting for the low recoveries recorded above.

It was found, however, that alcoholic solutions of phenothiazine when boiled for periods as long as four hours did not show any appreciable decomposition. Experiments were therefore carried out in which faeces containing known amounts of phenothiazine were extracted with alcohol for four hours. Table 3 shows the results that were obtained.

TABLE 3.—RECOVERY OF PHENOTHIAZINE FROM FAECES BY EXTRACTION WITH ALCOHOL FOR FOUR HOURS.

Phenothiazine Added.	Phenothiazine Estimated.	Recovery Per cent.
mg	mg	
39.0	37.7	97
36.2	33.1	92
21.9	20.4	93
8.9	8.2	92

These figures indicated that the method could be relied upon to estimate quantitatively free phenothiazine in sheep's faeces.

The following technique has therefore been adopted for routine analyses of faeces for phenothiazine. The mixed sample (usually 10 g.) is weighed, and dried at 100° C. for two hours after which it is weighed again. It is then Soxhlet-extracted with alcohol for four hours. On cooling, the extract is made up to 100 ml. in a standard flask. An aliquot portion (1 ml. to 10 ml.) is then measured out and used in estimating phenothiazine by the method of Eddy and De Eds (*loc. cit.*).

This has been applied to the analyses of faeces collected from sheep dosed with phenothiazine, results of which will appear elsewhere.

3. Acknowledgments.

The author would like to express his appreciation for the helpful suggestions given by his colleague, Mr. M. R. Freney, during the course of this work.

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A Preliminary Note on the Anthelmintic Efficiency of Phenothiazine against *Trichostrongylus* Spp. in Sheep.

*By Hugh McL. Gordon, B.V.Sc.**

1. Introduction.

Trichostrongylosis of sheep is a very potent cause of economic loss, particularly in young sheep, and at times is the cause of considerable mortality in weaners.

The search for an anthelmintic possessing efficiency against *Trichostrongylus* spp. inhabiting the small intestine of sheep has formed one of the major activities of the parasitology section of the McMaster Animal Health Laboratory. This work reached a temporary objective in 1935, when critical tests showed that a mixture of copper sulphate and nicotine sulphate was reasonably efficient against these parasites (Gordon, 1935). McEwen (1935) had reached the same objective as a result of field trials in England.

Further experiments (Gordon and Clunies Ross, 1936) showed that sheep dosed daily with 4,000 *Trichostrongylus* spp. larvae, and treated at intervals of three weeks with a mixture of copper sulphate and nicotine sulphate, were protected against trichostrongylosis. In this experiment, treatment at similar intervals with tetrachlorethylene, following a preliminary dose of copper sulphate, also protected against trichostrongylosis.

Since 1935 the mixture of copper sulphate and nicotine sulphate has been widely used in Australia in the control of trichostrongylosis, and it has given reasonably satisfactory results when employed regularly and in conjunction with improved husbandry practices, particularly those aimed at raising the plane of nutrition of young sheep. However, in severe outbreaks, this mixture has not always shown satisfactory efficiency.

A full account of experiments dealing with tests of a number of anthelmintics against *Trichostrongylus* spp. will be published in the near future.

2. Experiments with Phenothiazine.

The high degree of efficiency shown by this drug against such widely different species as *Haemonchus contortus* and *Oesophagostomum columbianum* (Harwood, Habermann, and Jerstad, 1939), (Gordon, 1939), (Gordon and Whitten, 1939), (Roberts, 1939), prompted the hope that it would also prove effective against *Trichostrongylus* spp., a hope that seemed the more likely of fulfilment when Harwood et al. (1939) observed its marked efficiency against *Ostertagia* spp.

Preliminary trials have now been carried out on sheep which have been artificially infected with *Trichostrongylus* spp., thus permitting the effect of treatment to be judged by faecal egg counts.

* A Senior Research Officer of the Council's McMaster Animal Health Laboratory, Sydney.

The trials have now been completed, and the results are as follows:—

Experiment 1.

Five sheep received doses of 0.6 gramme per kg. body weight of a proprietary phenothiazine preparation (Thiox) administered in gelatine capsules. The number of *Trichostrongylus* spp. eggs per gramme of faeces was reduced by 93, 97, 96, 99, and 93 per cent respectively.

Experiment 2.

Three sheep received doses of 0.3 gramme Thiox per kg. body weight, administered in capsules. The number of *Trichostrongylus* spp. eggs per gramme of faeces was reduced by 70, 30, and 80 per cent. respectively.

Experiment 3.

Eight sheep received doses of 0.3 gramme Thiox per kg. body weight. The drug was administered in capsules to four of the animals, and shaken up in 30 ml. 2 per cent. copper sulphate solution for the remaining four.

In those receiving the drug in capsules, the number of *Trichostrongylus* spp. eggs per gramme of faeces was reduced by 91, 91, and 84 per cent. respectively in three sheep. The fourth sheep died from the effects of severe trichostrongylosis four days after treatment, but it had shown a very marked reduction in egg count.

In the sheep receiving the drug shaken up in copper sulphate solution, the number of *Trichostrongylus* spp. eggs per gramme of faeces was reduced by 71, 45, and 95 per cent. respectively in three animals. The fourth sheep died from the effects of trichostrongylosis four days after treatment, but it had shown a very marked reduction in egg count.

Experiment 4.

Six sheep received doses of 0.15 gramme Thiox per kg. body weight, administered in capsules to three, and shaken up in 30 ml. 2 per cent. copper sulphate solution to the other three. In no case did the reduction in egg count exceed 50 per cent.

3. Conclusions.

Phenothiazine, in the form of the commercial product Thiox, in doses of 0.6 gramme per kg. body weight, administered in capsules, showed a very high degree of efficiency against *Trichostrongylus* spp. in sheep. When the dose was reduced to 0.3 gramme per kg. body weight, the degree of efficiency obtained was also reduced, but was satisfactory in nine out of eleven sheep treated (i.e., it reduced egg counts by 70 per cent. or more). Further reduction of the dose to 0.15 gramme per kg. body weight resulted in a marked decrease in degree of efficiency.

It is noteworthy that in Experiment 3 phenothiazine was equally efficient whether administered in capsules or as a powder shaken up in copper sulphate solution. From this it would appear that passage of the drug directly into the abomasum is unnecessary. Further observations will be made on this point, however, as it is possible that in these three sheep the copper sulphate failed to induce reflex closure of the oesophageal groove.

The high degree of efficiency of this drug against *Trichostrongylus* spp. in sheep represents an extremely important advance in the control of these parasites, and indicates that phenothiazine is likely to have a very wide and valuable application in the control of the more important nematodes of sheep in Australia (*Oesophagostomum columbianum*, *Haemonchus contortus*, and *Trichostrongylus* spp.).

4. References.

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A Preliminary Note on the Chemotherapy of Oesophagostomiasis of Sheep with Special Reference to the Efficiency of Phenothiazine.

By Hugh McL. Gordon, B.V.Sc.

Erratum.

An error occurred on page 204 of this article which appeared in the previous issue. In the 10th line "0.06 to 0.5 g." should have read "0.06 to 0.5 grain".

Radio Research Board — 11th Annual Report.

For the year ended 30th June, 1939.

The Radio Research Board of the Council is now constituted as follows:—Professor J. P. V. Madsen (University of Sydney), (Chairman), Sir Harry Brown (Director-General, Postmaster-General's Department), Professor T. H. Laby, F.R.S. (University of Melbourne), and Commander H. M. L. Waller, R.A.N. (Department of Defence). The previous Annual Report of the Board was published in this *Journal* (**11**: 328, 1938).—Ed.

1. General.

The Board has continued to concentrate its attention on (i) propagation problems and (ii) atmospherics. The work on propagation involves a study of the conditions in the ionosphere and the way in which those conditions change from time to time; it is centred at the P. N. Russell School of Electrical Engineering at the University of Sydney. The work on atmospherics is being carried out in the Natural Philosophy School of the University of Melbourne.

During the period under review there has been a change in the personnel of the Board. Commander E. H. N. Harvey, R.N., returned to England, and towards the end of the period Commander H. M. L. Waller, R.A.N., was appointed in his stead.

2. Work at Sydney.

Observations on the ionosphere have been proceeded with on similar lines to those used in previous years, but, with improvements in apparatus and technique, more detailed information is being obtained.

The latest model of the P′f, or automatic effective height, recorder constructed at the Commonwealth Solar Observatory covers the range of frequencies from 2 to 13 Mc./s. in $2\frac{1}{2}$ minutes and can be operated continuously, or at intervals of $7\frac{1}{2}$ minutes or of 30 minutes. The Liverpool apparatus records echo heights and intensities continuously for $2\frac{1}{2}$-minute periods alternately on each of two frequencies near the critical frequency; the critical frequency can therefore be deduced almost continuously.

The observations to determine the polarization of the anomalous echo observed on frequencies below the "gyro-frequency" were successful. Its polarization was found to vary from almost linear to elliptical with the same sense of polarization as the extraordinary ray. A paper on this subject has been published in "Terrestrial Magnetism and Atmospheric Electricity." A full discussion of the question with Dr. L. V. Berkner of the Carnegie Institution of Washington helped to clear the issues, and it was agreed that additional observations at locations near the magnetic poles were desirable.

The connection between conditions in the F_2 region of the ionosphere and meteorological conditions at the ground has been definitely established, and a paper entitled "The Association of Meteorological Changes with Variations of Ionization in the F_2 region of the Ionosphere" is in process of publication. The subject was discussed at a joint meeting

of the Chemical Society, the Physical Society, and the Royal Meteorological Society in London. A review of this discussion appears in *Nature* **143**: 1074 (June 24, 1939).

The "pulse-phase" equipment for recording very small changes in ionospheric heights has passed its preliminary tests satisfactorily and is being prepared for regular observations.

The Board has been considerably assisted in its work at the Sydney end by the co-operation of several allied workers.

In the Department of Electrical Engineering in the University of Sydney, Dr. J. H. Piddington is constructing a high-power short wave transmitter and receiver, especially designed to give high resolution of echoes with small time separation. The particular object of this equipment is the further investigation of reflections from regions below the ionosphere proper.

A new radio method of distance-measuring was suggested by Professor Madsen, and the technique developed by Dr. Piddington assisted by Mr. Hibbard (a Commonwealth Research Scholar). This is a derivation from the pulse method in which the repetition frequency of the pulses is determined by the time interval between the sending and receiving of a pulse. Thus the recurrence frequency of the pulses constitutes an audio frequency note, the pitch of which determines the distance of the reflecting object. The method is particularly useful for determining small changes in layer heights.

The radio investigations at Mount Stromlo, referred to in previous reports, are being continued by Mr. A. J. Higgs of the Commonwealth Solar Observatory staff.

It is a source of satisfaction to the Board and a stimulus to its workers to find a number of kindred investigations being carried on in other institutions most suited to undertake them.

In the Department of Physics of the University of Sydney, Professor V. A. Bailey and his co-workers are conducting some very interesting investigations of the possible effects of radio waves on the ionosphere. Work has proceeded on two main lines; first, a theoretical examination of the expected effects, using the best available data, and secondly, laboratory experiments to reproduce expected phenomena on a laboratory scale and so provide more accurate material for theoretical predictions.

The theoretical investigation, in which Professor Bailey was assisted by Mr. J. Somerville, has been facilitated by the development of abbreviated methods of computation, of general methods of solving differential equations graphically, and the construction of a "Vectinvertor" which combines mechanical and graphical methods for the computation of polarization, refractive indices, and coefficients of absorption.

One interesting result has been the prediction of the possibility of producing an artificial aurora if sufficient radio power could be made available. This phenomenon has now actually been produced on a laboratory scale using wave lengths of the order of 50 cm., and the "gyro-frequency" resonance was clearly demonstrated. This work was carried out with the assistance of Mr. C. S. Davis (Commonwealth Research Scholar), and later of Miss J. Freeman.

Dr. R. B. Makinson and Mr. W. H. Robertson are investigating the potentials necessary to produce a visible glow in gases under conditions similar to those in the ionosphere, while Dr. R. H. Healey and Mr. C. B. Kirkpatrick are studying the motions and attachments of electrons in oxygen and ozone.

Also at the University of Sydney in the Department of Physics, Dr. S. E. Williams (Commonwealth Research Fellow) has been engaged upon research concerned with the measurement of the absorption by atmospheric gases of the radiation of hydrogen (1215.6 Angstrom) thought to be concerned in the production of fade-out ionization in the upper atmosphere. The absorption by molecular nitrogen, molecular oxygen, air, and water vapour has been determined for this region of the spectrum. The first section of this work is now completed and ready for publication and should provide a sounder practical basis for the theoretical investigations of the absorption of solar radiation in the atmosphere.

At the Commonwealth Solar Observatory, Mount Stromlo, Mr. A. J. Higgs is carrying out observations on atmospheric ozone, Mr. R. G. Giovanelli is observing bright hydrogen solar eruptions (an investigation which was commenced by Dr. Williams), and Dr. C. W. Allen is making a study of the solar spectra and hydrogen "bombs," all of which observations are being carefully watched for correlation with ionospheric changes.

Mr. G. H. Godfrey and Mr. W. L. Price, of the staff of the Sydney Technical College, are making a theoretical investigation of the absorption of solar radiation in the upper atmosphere. One paper has been published, and further work is in progress.

Arrangements have been made for the interchange of ionospheric data with the British Radio Research Board, the Carnegie Institution of Washington, and the New Zealand Radio Research Board. This interchange of data should prove most valuable in the investigations of the Australian Radio Research Board.

Commonwealth meteorological officers have also been helpful in supplying data for correlation purposes. Considerable assistance on the more practical aspects of the design and construction of equipment has been given by the staff and research students of the Electrical Engineering Department of the University of Sydney and by officers of the Postmaster-General's Department.

During the year the Board's officers had the opportunity of meeting many distinguished overseas scientists at the meeting of the Australian and New Zealand Association for the Advancement of Science and elsewhere, and of discussing common problems. The visitors included Sir George Simpson from England, Dr. Berkner from America, and the late Dr. Kidson from New Zealand.

3. Work at Melbourne.

Work on Atmospherics.

The investigation on reflection of atmospherics at the ionosphere was continued during the past year, and a large proportion of oscillograms of atmospheric waveform were found to show the presence of reflected waves. An analysis of fourteen oscillograms from sources

distant 180 to 1,050 km. gave values 54 to 83 km. for the height of the reflecting layer. Evidence was obtained that does not support the suggestion of some recent writers that the ground wave has a velocity less than that of light. The values observed for the various time intervals between the arrival of the ground wave and the various sky waves seem incapable of explanation if such a difference existed. The complete results of the investigation have been written up and have been sent to the Royal Society for publication.

The suggestion was made in the last annual report that the height of the reflecting layer and the distance of the source mainly determine the character of an oscillogram. This suggestion has been confirmed by Professor B. F. J. Schonland and his co-workers in South Africa, in a recent letter to *Nature* (**143**: 893, 1939); they state that a study of their own records strongly supports the view of the Australian workers that the structure of an oscillogram arises from repeated reflections, but brings to light a new feature which can be interpreted as a pronounced lowering of the effective height of the layer in the neighbourhood of the parent storm.

An important aspect of the results obtained from the reflection of atmospherics at the ionosphere is the information obtained about the behaviour of the ionized layer when the wave reflected is of very long wavelength. In the case of an atmospheric, the "equivalent wavelength" can be taken from 20,000 metres upwards. Normal methods using a pulse transmitter for determining the layer height have not been applied at these long wavelengths owing to technical difficulties. The radiation resistance of an aerial system becomes so low at these wavelengths that very little power can be radiated, but this difficulty is overcome in the case of a lightning flash, as the power radiated is extremely great.

The cathode ray direction finder was completely overhauled during the year. Each unit was rack-mounted, and all circuits were adjusted and aligned. Final adjustments were carried out in the building in Royal Park, where the direction finder has been set up. By a change in the coil aerials, the minimum wavelength to which the direction finder can be tuned is being reduced from 3,000 metres to 850 metres.

In a recent report of the Radio Research Board (Coun. Sci. Ind. Res. (Aust.) Bull. No. 127), Dr. H. C. Webster, G. H. Munro, and A. J. Higgs have published the results obtained by further studies of directions of atmospherics at Toowoomba and Canberra. From the data given in the report, it seems likely that the probability of aircraft encountering thunderstorms when traversing specified air routes might be determined; this matter is being pursued. The greater duration of sea sources than of land sources is again clearly evident, but it is noted that the trans-Tasman routes, particularly the Sydney-Auckland route, are comparatively free from thunderstorms.

Ultra-High-Frequency Work.

Mr. F. J. Kerr, a research scholar of the Melbourne University, has been assisted by an apparatus grant to investigate the refractive indices of gases for wavelengths in the region of about 2 to 5 metres. These waves are not reflected by the ionosphere, but are bent round the earth by diffraction and refraction. In view of the increased

application of ultra-short waves, it is desirable that the changes in refraction with changes in composition of the atmosphere should be calculable. No measurements of the refractive indices of air or its constituents, however, appear to have been made between about 70 metres and the infra-red region.

In the experiments referred to, standing waves are produced in a gastight concentric-tube Lecher circuit by bringing it into resonance with a crystal-controlled oscillator to which it is loosely coupled. The changes in the length of these standing waves, as the pressure or composition of the gas inside is varied, can be determined with some precision. A preliminary value for the refractive index of air has been obtained, and it is proposed shortly to study water vapour and oxygen.

Work in Melbourne during the past year was not carried out without interruption. Building alteration at the Department of Natural Philosophy, containing the radio research laboratory, necessitated the transfer of equipment to a temporary location while a new laboratory was completed. These interruptions necessitated a considerable amount of moving of stock. The new laboratory, which offers considerably increased facilities, is at present being set out.

4. Publications.

The following publications have appeared during the past year as a result of the investigations carried out by the officers of the Board and by independent investigators who have been closely associated with these officers:—

(*a*) *Publication of the Council for Scientific and Industrial Research.*

Bulletin 127.—" Radio Research Board: Report No. 14." (1) " Further Studies of Directions of Atmospherics at Toowoomba and Canberra," by H. C. Webster, Ph.D., F.Inst.P., G. H. Munro, M.Sc., A.M.I.E.E., and A. J. Higgs, B.Sc.

(*b*) *Other Publications.*

1. " The Lorentz ' Polarization ' Correction and the Behaviour of Radio Echoes from the Ionosphere at Frequencies near the Gyro-Frequency," by D. F. Martyn, D.Sc., and G. H. Munro, M.Sc. *Nature*, **142**: 1159, Dec. 31, 1938.

2. " The Lorentz ' Polarization ' Correction in the Ionosphere," by D. F. Martyn, D.Sc., and G. H. Munro, M.Sc. *Terrestrial Magnetism and Atmospheric Electricity*, **44**: 1, March, 1939.

3. " Concerning the Nature of Radio Fadeouts." Letter to *Physical Review*, May 15, 1939. D. F. Martyn, D.Sc.

4. " Recent Solar Eruptions, Auroras, and Magnetic Storms," by A. J. Higgs, B.Sc., and R. G. Giovanelli, M.Sc. *Nature* **141**: 746, April 23, 1938.

5. " The Association of Radio Fadeouts with Solar Eruptions," by R. G. Giovanelli, M.Sc., and A. J. Higgs, B.Sc. *Terrestrial Magnetism and Atmospheric Electricity*, **44**: 181, June, 1939.

6. " Reflection of Atmospherics by the Ionosphere," by T. H. Laby, M.A., Sc.D., F.R.S., F. G. Nicholls, M.Sc., A. F. B. Nickson, M.Sc., and J. J. McNeill, M.Sc. *Nature*, **142**: 353, August, 1938.

5. Acknowledgments.

Once again acknowledgment is due to a number of organizations and individuals for the valuable co-operation they have furnished. The help of the Postmaster-General's Department, of the Universities of Sydney and Melbourne, of the Department of Defence, and of the Solar Observatory, Mount Stromlo, has continued as hitherto. Valuable assistance has also been rendered by a number of independent investigators, who were indicated in the main parts of this report.

To all who have helped in this way the thanks of the Board are gratefully tendered.

An Artificial Dryer for Wood Wool.

*By C. E. Dixon, M.Sc., A.A.S.E.**

1. Introduction.

Although timber-drying kilns have now been brought to a high standard of perfection and are firmly established as a complete necessity for the better utilization of timber, drying kilns or dryers for drying specialized products are often non-existent or very crude.

This seems to be the position with regard to the drying of wood wool. At present, the most usual method of drying—or attempting to dry—wood wool is to spread it around on the factory floor, or on wire benches or trays, and let it air-dry. This method has serious disadvantages. In the first place, on account of the great " bulk " of wood wool, the space required is enormous. Secondly, the drying rate is too slow, particularly if the wool is to be dried sufficiently under winter conditions—if, indeed, it is possible to dry it sufficiently under such conditions. Furthermore, uniform drying is not easily possible, so that it is probable that the wool will contain wet patches, when dried in such a manner.

On the other hand, attempts to dry the wood wool artificially have not always been successful, and have usually been costly.

As a result of the foregoing and in view of the demand for a wood wool dryer, experimental data on the drying of wood wool have been obtained by the Division of Forest Products, C.S.I.R., and designs for the wood wool dryer, here described, drawn up.

2. Preliminary Tests.

In most drying problems, the first and most important consideration is circulation—that is, the drying plant must be capable of subjecting the material to be dried to a brisk and uniform circulation.

Obtaining a brisk circulation usually presents no great difficulties, but obtaining a uniform circulation, that is, subjecting all the drying material to air circulating at one and the same rate, is generally not so easy of attainment.

It seemed probable that the best way of attaining this uniform circulation, so far as wood wool was concerned, was to have the wood wool distributed in a uniform layer on a slotted rack, and to blow air upward (or downward) *through* the layer and not *along* the layer as has usually been attempted.

If, moreover, this rack were made in the form of a travelling belt, or conveyor, the drying of the wood wool could be controlled by regulating the rate of travel of the conveyor, and the humidity and temperature of the circulating air.

In order to test out the practicability of such a travelling rack type of dryer, a small experimental plant of this type was constructed at the Forest Products Laboratory, Melbourne. The conveyor was made by fastening 1-in. wooden slats, with 1-in. spaces between them, on two endless leather belts passing over two drums.

* Seasoning Section, Division of Forest Products, C.S.I.R.

The tests carried out with this plant proved entirely satisfactory, and demonstrated that green wood wool could be dried down to a satisfactory condition for use—about 18 per cent. to 20 per cent. moisture content—in from two minutes for finest grades to six minutes for coarse grades, by heated air circulating at the rate of 260 feet per minute through an 8-in. layer of the wool, at a temperature of 140°F. and a relative humidity of 35 per cent.

3. Design of Commercial Dryer.

As a result of the information yielded by these experiments, it has been possible to design a commercial wood wool drier of sufficient capacity to deal with the output of one 4-cutter machine, that is, 200 lb. (wet weight) of wood wool per hour.

This drier, which is shown in Fig. 1, is of the conveyor or progressive type, and has overall dimensions of about 20 feet by 10 feet, with a height of 7 feet.

The effective length of the conveyor is 12 feet, that is, the length of conveyor in the drying chamber at any one time is 12 feet, and this also is the length of the drying chamber. With 3-ft. diameter conveyor drums, and allowing $16\frac{1}{2}$ inches clearance between the drum and the drying chamber, at the entering end of the dryer, and $4\frac{1}{2}$ inches at the leaving end, the total length of the conveyor is 37 feet. The width of the conveyor is 4 ft. 6 in. The conveyor may be made by fixing (nailing, stapling, or rivetting, &c.) $\frac{3}{4}$ in. by $\frac{3}{4}$ in. wooden slats on to leather or other belting, with $1\frac{1}{2}$-in. air spaces between the battens. The drums, which are 3 feet in diameter, may also be of simple wooden construction.

The drying chamber may conveniently be of frame and plywood construction, provided with detachable panels for easy access to the inside of the drying chamber. Simple sliding ventilators are provided in the roof of the drying chamber, and wet and dry bulb thermometers are placed through the wall of the drying chamber, below the conveyor level.

The air circulation—260 feet per minute through the wood wool—may suitably be produced by two 30-in. diameter propeller fans, running at 340 r.p.m. on $1\frac{1}{2}$-in. diameter shafts, and driven by a $1\frac{1}{2}$-h.p. electric motor (which may also be used to supply the power for driving the conveyor). If the motor speed is 1,440 r.p.m., then a $3\frac{1}{2}$-in. diameter motor pulley driving on to a 15-in. diameter fan pulley will give the required fan speed.

Heat is supplied either by steam heating coils or, preferably, by steam heated finned radiators, capable of "radiating" 200,000 B.T.U. per hour under brisk air circulation conditions. A 6-8 h.p. boiler (i.e., one capable of evaporating 200 to 250 lb. of water per hour) will be needed to supply steam to the dryer.

The disposition of the fans, radiator, baffling, &c., is shown in the figure. The baffling must be so constructed that the air is forced up through the wood wool on the effective length of the conveyor, and

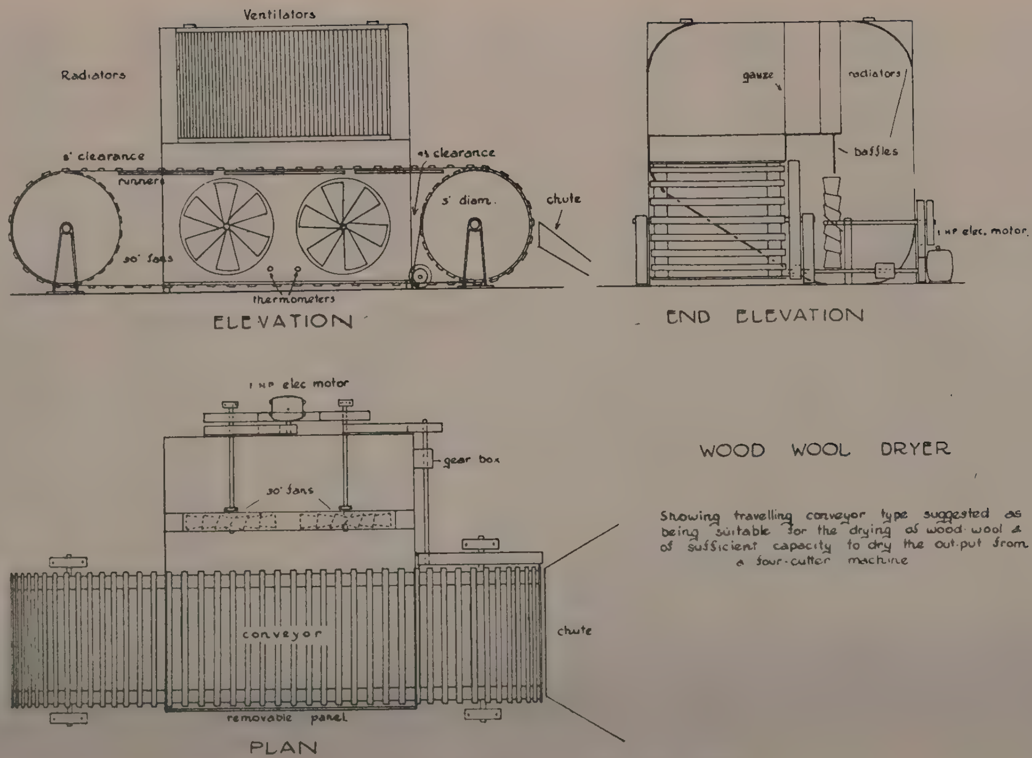

Fig. 1.—Suggested design for wood wool dryer.

re-circulated through the radiator and fans without any short-circuiting occurring. In order to ensure this, the partition or baffle in which the radiator and the fans are situated, must be so constructed that it extends right to the walls, ceiling, and floor of the drying chamber, and that the only places at which it will allow the passage of air are through the radiator and the fans. Also the horizontal baffle above the fans must be air-tight in order to force the air up through the wood wool before re-circulating back through the radiator and fans.

The conveyor travel of 2 feet per minute may conveniently be obtained by a drive direct from one of the fan shafts (that is, without using a pulley on the shafting) through a gear, or worm-reduction, box and then on to the drum itself. Then, for a fan shaft diameter of 1½ inches and speed of 340 r.p.m., driving on to a 9-in. diameter pulley on the gear box and from a 6-in. pulley on the low speed side of the gear box straight on to the periphery of the 3-ft. drum, the gear box would have to have a reduction ratio of 45 to 1, and a minimum torque strength of 425 inch-pounds on the low speed shaft of the gear box. If the drive from the gear box is on to an 18-in. diameter pulley on the drum shaft, then the reduction ratio of gear box would have to be 90 to 1 and the minimum torque strength 850 inch-pounds.

4. Operation.

Control of the drying rate can best be obtained by temperature manipulation, i.e., by regulating the supply of steam to the heating coils or radiators—throttling down for the finer and faster drying wood wools and, conversely, opening up the steam valve for the coarser grades.

No precise rules can be laid down as to the exact temperatures required, as these will depend on a number of local as well as general factors, such as the moisture condition and species of the wood wool, the size of strand of the wool, drying plant characteristics, the period of the year, &c., and will have to be determined by experience at each individual plant.

The actual drying conditions, required from time to time, can readily be adjusted by the operator, who will know from the "feel" of the wool leaving the dryer, and from experience, correlated with a knowledge of the wet and dry bulb behaviour, whether to shut off or whether to release more steam. As the circulating air in the dryer is heated only, and not humidified by the addition of any live steam—there being no steam sprays in the dryer—it is probable that the dry bulb temperature will be the operator's main guide, since, under these conditions, it is an indication not only of the air temperature, but is also to a certain extent a measure of the relative humidity. On the other hand, it must not be forgotten that, as the humidity in the dryer will be dependent on the degree of ventilation and on changing outside atmospheric conditions, a knowledge of the wet bulb temperature will be necessary in order to interpret completely the conditions in the dryer.

The valve controlling the supply of steam to the radiators should, for the sake of convenience, be readily accessible to the outlet end of the dryer.

If different rates of conveyor travel are desired, this can be brought about by means of a cone pulley drive from the fan shaft to the gear box. But it must be remembered that, if the rate of conveyor travel is altered, the drying time will be altered proportionately. Also, the capacity of the dryer will be similarly altered if the wood wool is fed on to the conveyor in a layer of the same thickness. If, however, the wood wool is fed on to the conveyor automatically, as it comes off the cutting machine, then the capacity will remain the same, but the layer thickness will alter. In the latter case, the alteration in the layer thickness will tend to be neutralized by the alteration in the drying time. With some plants, and under some conditions, a thinner wood wool layer than the 8-in. layer used in these experiments may prove more satisfactory.

The wood wool should not be bunched or knotted, but should be spread out or "teased" in an even layer over the conveyor to prevent uneven drying taking place. If the wood wool cutting machine is on the floor above the dryer, the wool may be fed down on to the dryer conveyor by means of a chute. When the cutting machine is on the same floor as the dryer, a travelling belt could be used for conveying the wool to the dryer.

A Study of the Bending Qualities of Karri (*Eucalyptus diversicolor*).

*By R. S. T. Kingston, B.Sc., B.E.**

Summary.

The bending qualities of karri (*Eucalyptus diversicolor*) have been studied, and the relative importance of each of the various factors affecting the results has been assessed; one of the most important was found to be moisture content. The most suitable moisture content appears to be between 25 and 40 per cent., air-dry material being distinctly inferior in bending quality to material at a higher moisture content. At least for bends with radius-thickness ratios of 6 or more, 600 to 800 lb. per sq. in. appears to be a suitable range of end pressure (180° bends). A minimum steaming period of one hour per inch of thickness was found to be adequate, whilst one hour in the straps after bending proved sufficient.

Backsawn and quartersawn material were found to bend equally well if free from checks. Checks, however, caused more wastage in selection with backsawn stock than with quartersawn stock.

The first part of this report sets out the principal results of the tests in non-technical language, whilst the second part, which will be of interest only to a comparatively limited number of readers, gives the detailed methods of analysis.

Part I.

1. Introduction.

The experiments described here represent the first of a series of detailed studies of the bending properties of various Australian timbers. In this series of investigations, only timbers which have been found during the reconnaissance studies to bend well and which are readily obtainable in bending quality and in considerable quantity will, in general, be included.

Whilst karri is not one of our best bending timbers for very sharp bends, it bends easily and well, provided the bend it not unduly severe, and is largely used for bends such as those required for agricultural implements.

There are so many factors involved in the bending of wood that only a few of these could be studied here. Others may be investigated later. Previous tests have shown the importance of moisture content, which was therefore among the factors studied. The other factors considered were—

1. Variation of the duration of the preliminary steaming process.
2. Variation of longitudinal pressure on the end of the stick during bending.
3. Direction of the growth rings.
4. Variation of radius.
5. The speed of bending.
6. The time during which the bends are left in the straps after completion.

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2. Resumé of Results.

The material used in these tests was taken from four trees, faulty material being rejected. The bending blanks were machined on all faces to a finished size of 2 inches by 1 inch, half being air-dried and half bent in a semi-green state.

In the main experiment two replications were used, each involving 288 bends including bending conditions which covered every possible combination of the following conditions, viz., 25 and 14 per cent. moisture content, 8 inches and 12 inches radius, 1, 3, and 5 hours steaming, 600, 900, and 1,200 lb. per sq. in. end pressure, $\frac{1}{2}$ and $1\frac{1}{2}$ R.P.M. as speeds of rotation of the table of the bending machine, 2 and 24 hours setting in the straps.

In addition to this, a subsidiary experiment, designed to test the relative bending quality of backsawn and quartersawn material, was performed; 124 blanks, also 2 inches by 1 inch in cross section, being prepared for bending to a radius of 6 inches. Half of these were quartersawn and half backsawn. In both main and subsidiary experiments, steam at atmospheric pressure was used. The radial force applied to the wood at the point of bending was 1,250 lb. in the main experiment and 1,000 lb. in the subsidiary, the latter being found quite sufficient. In the subsidiary experiment the end pressure was fixed at 750 lb. per sq. in., this figure being chosen after the main experiment was completed. In this case, moisture content groups varying from 25 per cent. to 40 per cent. were used. The work was carried out on the machine described by Kingston (1). The method of grading the completed bends is also described in that article.

It was found that material at a moisture content of 25 per cent. bent considerably better than at 14 per cent., and that an increase of moisture content up to 40 per cent. did not cause any decrease in the bending qualities of the material. Experimental trials showed that the end pressure should be at least 600 lb. per sq. in. Pressures above this up to 1,200 lb. per sq. in. caused no appreciable increase in the number or severity of compression failures, but gave rise to occasional buckling as a long column. One hour steaming and two hours setting in the straps proved sufficient. Before the bends are removed from the straps, however, they should have a wooden tie tacked across the end to keep them in shape until required for use. A speed of rotation of the table of 1.5 R.P.M. proved satisfactory Higher speeds have not yet been investigated.

Checks caused slightly more trouble in the case of backsawn stock, but otherwise no difference was detected between the bending quality of backsawn and quartersawn material. The grading average for the bends which were carried out at 6-in. radius was 74 per cent. For comparison with other species, reference should be made to a previous article (1). It is particularly noticeable in the case of karri that slight defects, such as knots, gum-veins, checks, and cross-grain, cause considerable degrade in the case of a relatively severe bend (radius-thickness ratio 8 or less), so that the material for bending stock should be selected with care to save wastage. This should not however, be difficult, as karri is a remarkably clear timber, checks being the defect most likely to be encountered.

Part II.

1. Selection and Conversion of Material.

The material was taken from four trees which were selected for standard strength tests. The logs were obtained from Pemberton and Jardee (W.A.) at altitudes of approximately 550 and 900 feet respectively above sea level. The rainfall in these areas is about 55 and 50 inches respectively, and the forest in both localities consists of pure karri stands. The trees were all between 185 and 225 feet in height with a girth breast high of from 13 feet to 20 feet. All were straight trees with well-balanced crown.

The aim in selection was to obtain a maximum amount of material free from defect, which is reasonable, as in this species faulty material occurs only in relatively small quantities and is easily eliminated in conversion. The material set aside for bending was sawn into sticks each $2\frac{1}{2}$ x $1\frac{1}{2}$ inches in cross section and 4 feet long, an equal amount of backsawn and quartersawn stock being obtained. The selection of backsawn and quartersawn material could not be made at random from the material available without considerable waste, a fact which had to be taken into account in designing the experiment.

2. Experimental Design.

It was impossible here, without using an excessive amount of material, to consider a large number of levels for each of the factors studied, and the experiment was confined to two or three levels in each case, mostly fairly widely apart, so that at least the importance of variation of each factor could be gauged even if no quantitative results could be obtained.

It was decided to use some type of factorial experiment (2), and to decide from the results of this what type of experimental design would be used in future for tests of a similar nature. Owing to the fact that the material was not divided at random into backsawn and quartersawn blanks, a "simple" factorial experiment could not be used. It was decided that a "split-plot" design (3) was most suitable. This name is taken from agricultural experimentation, in which connection the design was first developed. It is the relevant design in the present case because, as has already been mentioned, the test material has been divided into two groups, one backsawn and one quartersawn. In other words, it was not decided at random whether any particular piece should be backsawn or quartersawn, whereas with the other factors the selection was completely random.

Two replications were used, each being split into two sub-groups (sub-plots) containing respectively backsawn and quartersawn blanks. The division of both backsawn and quartersawn material between the two replications was made at random. The remaining factors were considered at the following values:—

1. Moisture contents—25 per cent, 14 per cent.
2. Radii—8 inches, 12 inches.
3. Steaming time—1 hour, 3 hours, 5 hours.
4. End pressure—600 lb./sq. in., 900 lb./sq. in., 1,200 lb./sq. in.
5. Speed of bending—0.5 R.P.M., 1.5 R.P.M.
6. Setting time in straps—2 hours, 24 hours.

Each replication thus involves five factors at two levels and two at three levels in each sub-plot, which thus consists of $2^5 \times 3^2$ specimens, the whole experiment involving 576 bends.

Since there are only two replications, a comparison between the bending quality of backsawn and quartersawn material would have no reliability, hence a separate subsidiary experiment was conducted to test the significance of the difference. In this test a radius of 6 inches was used so that the test would also provide figures for comparison with the reconnaissance figures at this radius. In this experiment a total of 49 backsawn and 62 quartersawn bends were carried out. The specimens were steamed at 100° C. and atmospheric pressure in all cases. In both experiments the time interval between removal from the steaming vessel and commencement of the bending operation was 30 seconds. The blank was 2 in. by 1 in. in cross section. A radial force of 1,250 lb. was used for the split-plot experiment and 1,000 lb. for the small experiment on sawing method. In the subsidiary experiment a steaming time of 1 hour was again used, together with an end pressure of 750 lb. per sq. in. The material used in this experiment was at moisture contents varying from 25 to 40 per cent., there being an approximately equal number of backsawn and quartersawn specimens at any one moisture content.

3. Method of Test.

The backsawn and quartersawn material for each replication was divided at random among the treatments by means of a pack of cards, each labelled with a number corresponding to a treatment. The cards were shuffled for about 15 minutes, being periodically divided into sub-packs which could be more conveniently handled, these being then shuffled in such a way as to prevent non-random selection due to cards sticking together.

The sticks to be tested air-dry were then stacked out for drying, and the sticks to be tested at 25 per cent. were dried down to a little above the required moisture content and then block-stacked in a constant-humidity vessel until required, the humidity being kept as near saturation point as possible. Specimens were dressed on all faces before being bent.

In both the air-dry and 25 per cent. material, one replication was completed before the other was commenced, in order to avoid as far as possible any variation in technique during the carrying out of each replication.

4. Results of Tests.

The results of the tests for the split-plot experiment are shown in Table 1 in the form of an analysis of variance. In the whole-plot analysis, neither the difference between backsawn and quartersawn stock nor between replications appeared to be significant. As there is only one degree of freedom available for the estimate of error, little reliability can be placed on these results, as has already been mentioned.

In the sub-plot analysis, two of the main treatments produced significant effects, namely, moisture content and radius. Thus a radius of 8 inches is sufficiently different from a radius of 12 inches to produce

TABLE 1.—ANALYSIS OF VARIANCE.

—	Variance due to—	Degrees of Freedom.	Sum of Squares.	Mean Square.
Whole plots ..	Replications	1	109·37489	109·37489
	Direction of growth rings ..	1	·13878	·13878
	Error	1	7·33507	7·33507
Sub-plots— Main effects	Moisture content	1	1010·70822	1010·70822**
	Steaming time	2	11·01020	5·50510
	End pressure	2	48·88570	24·44285
	Radius	1	249·37489	249·37489*
	Speed	1	·76377	·76377
	Setting time	1	·49989	·49989
1st Order interactions	Moisture content v. Direction of growth rings	1	43·89063	43·89063
	Moisture content v. Steaming time	2	21·84723	10·92361
	Moisture content v. End pressure	2	62·44097	31·22048
	Moisture content v. Radius	1	2·64062	2·64062
	Moisture content v. Speed	1	4·87674	4·87674
	Moisture content v. Setting time	1	·39063	·39063
	Other first order interactions	26	95·07987	3·65692
	Error	530	20569·74190	38·81083
	Total ..	575	3045·20475	5·29601

* Significant at $P = 0{\cdot}05$ level. ** Significant at $P = 0{\cdot}01$ level.

a significant decrease in the quality of the bend, the respective grading means being 5.1 and 6.4. This difference is significant at the 5 per cent. level of probability but not at the 1 per cent. level.

On the other hand, the moisture content gave a difference which was significant at the 1 per cent. level of probability. The reconnaissance studies have shown that a far wider range of moisture contents can be used without detriment with some species than with others. It is obvious, however, that the severer the bend, the more carefully must the best moisture content be chosen. In the case of karri, the material at about 25 per cent. moisture content bent better than that at 14 per cent. The averages were 7.1 and 4.5 respectively, showing that karri bends better in the vicinity of fibre saturation point than when air-dry. It is doubtful if an increase in moisture content above fibre saturation would improve the results further. A detailed study of the effect of moisture content variation with a number of timbers will be necessary before the effect of moisture content variation on bending quality can be properly understood.

End pressure did not prove significant at the levels used. Hence, whilst 600 lb. per sq. in. is sufficient to avoid tension failures, karri at 8-in. and 12-in. radius bends equally well over a range of pressure varying from 600 to 1,200 lb. per sq. in., the drop in grading due to compression failures not being appreciable at the higher figure. The actual averages

at 600, 900, and 1,200 lb. per sq. in. were 5.4, 6.0, 6.0 respectively. However, a few tests were carried out at a lower end pressure, and it became clear that, if the pressure was reduced much below 600 lb. per sq. in., tension failures commenced to become frequent.

Steaming time was not significant over the range of times adopted. It is therefore clear that as long as a minimum time sufficient to heat the specimen throughout be exceeded, a large increase in steaming time produces no appreciable reduction in grading. It was, however, noticed that with five hours' steaming the wood became rather soft, and a tendency to buckling as a long column during bending became noticeable. Unduly long steaming may, however, cause a certain amount of chemical decomposition. It is seen from the results for this factor that 1 hour for a 2-in. by 1-in. cross section is quite sufficient, the means at 1 hour, 3 hours, and 5 hours being respectively 5.6, 5.8, and 5.9.

An approximate computation indicated that a period of about 35 minutes would heat the core to 95°C. It was from this figure that the minimum time use, namely one hour was chosen, a suitable margin being added to cover uneven heating and the fact that 95°C. might not be quite high enough for satisfactory results. A study will be undertaken later to see how much further the steaming time can be reduced.

Setting times of 2 hours and 24 hours did not prove significantly different. Thus two hours is a sufficient time during which to leave the bends in the straps. It is possible that a very much shorter time is sufficient. This also needs investigation. The mean for 2 hours and 24 hours setting time in the straps only differed by one in the first place of decimals, being 5.7 and 5.8 respectively.. It is, however, necessary before removal from the straps to tie strips of wood across the faces of the bend near the ends to prevent any opening out of the bend during drying. These should be left in place until the bend is required for use. Even after some weeks a spring of over an inch was noticed in some cases on removal of the ties. If the bend is to be used after only a very short time, allowance should be made in the bending so that after spring the right amount of bend remains.

Finally, speed was not significant over the range tested, thus showing that at least up to 1.5 R.P.M. increase in speed is not detrimental. Speeds up to 3 or 4 R.P.M. will be investigated later.

First order interactions were all computed but none were significant, only one giving a mean square greater than the mean square for error and this only 13 per cent. in excess.

In the case of the subsidiary experiment to determine the presence of any significant difference between backsawn and quartersawn stock, 49 backsawn and 62 quartersawn sticks were bent. These had been cut from material derived from a number of trees, the smaller number of specimens being bent in the case of backsawn stock as, though 62 of each were originally selected, thirteen of these were discarded or culled owing to the presence of bad checks. The averages were not significantly different, and so we can say that backsawn and quartersawn karri bend equally well.

The average grading figure for these bends was 74 per cent. of maximum, which at 6 inches radius and 1 inch thickness shows that karri is about equal to quartersawn brown mallet or silver ash.

In the subsidiary experiment, groups, each consisting of the same proportion of backsawn and quartersawn material, were bent at moisture contents varying from 25 to 40 per cent. No significant difference was discovered, showing that karri bends equally well over this range. How far below 25 per cent. one can go before the bends begin to deteriorate has not been found. A few per cent. would probably, however, be immaterial.

The whole of the bends in the split-plot experiment were re-graded after some months to detect any possible degrade during drying. However, no appreciable difference was discovered.

Acknowledgments.

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The author also wishes to thank Dr. M. M. Barnard for collaboration in the statistical part of the work.

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The Preparation of a Wood Sample for Chemical Analysis.

By W. E. Cohen, D.Sc., and A. W. Mackney, M.Sc.**

Summary.

An examination of wood samples prepared by using (*a*) a mill with a cutting action (Wiley mill) and (*b*) a mill with an impact action (Christy and Norris mill) is reported.

The following conclusions have been reached:—

(1) The effect of very fine comminution permits some degradation of Cross & Bevan cellulose during subsequent analysis.

(2) It is possible to accept for analysis either the 60–80 mesh fraction or the 60 — †sample of mountain ash (*E. regnans* F.v.M.), a representative of the pulpwood class. The former is undoubtedly preferable because of the more uniform particle size, but in case of doubt, where woods may contain larger amounts of extraneous material, it would be safer to use the 60 — sample.

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* An officer of the Division of Forest Products.

† Throughout this paper, the term "— 60 sample" is used to indicate a sample of particle size retained by a 60-mesh sieve. Similarly, "60 — sample" indicates a sample of particle size passing through a 60-mesh sieve.

(3) Even when the milder action of the Wiley mill is applied to samples of jarrah (*E. marginata* Sm.), it is not possible to disregard the fines in preparing a sample for analysis. This wood is representative of those containing an abundance of extraneous material, and the only satisfactory available method for preparing a sample of it for chemical analysis is to comminute it in the Wiley mill to an "all through 60 mesh" sample.

1. Introduction.

The chemical composition of Australian woods has been the subject of investigation since the creation of the Division of Forest Products in 1929. During the early stages, the employment of methods developed in overseas laboratories was attempted. For the preparation of a wood sample for analysis, it was then standard practice to convert the wood to sawdust or raspings or to mill or grind it in a suitable mill and to select from the product a particular particle size fraction as representative of the whole wood. For example, it has been common practice to select for analysis the material which passes a 60 mesh and remains on an 80 mesh sieve, or, alternatively, that which passes an 80 mesh and remains on a 100 mesh sieve. Until quite recently, little attention has been paid to the preparation of wood samples for analysis, and few attempts have been made to determine whether the samples prepared and selected were actually representative of the wood.

Mahood (1, 2), in 1922, adopted the procedure of selecting an 80-100 mesh fraction in spite of the fact that, when compared with sawdust passing a 40 mesh sieve, it was found to be deficient in extractives. On the results of this investigation, the U.S. Forest Products Laboratory adopted the procedure of selecting a 60-80 or 80-100 mesh fraction to represent the wood sample. The rejection of fine material passing a 100 mesh sieve was apparently influenced by the fear that comminution to such a fine state would cause breakdown of some of the major constituents. Until the recent work of Campbell and Bryant (3), practically no attempt has been made to justify this arbitrary selection of a portion only of heterogeneous material with the accompanying rejection of a finer portion which has been shown in this laboratory (4) to be enriched with finely-divided extraneous substances when dealing with a number of Australian eucalypt woods.

Owing to the peculiar composition of some of the eucalypt woods which have an abundance of extraneous material in their ray cells, vessels, and fibre lumina, it was soon discovered that samples prepared according to overseas procedures could not be accepted as truly representative of these woods. On account of the brittle nature of the extraneous substances, they easily segregated to the finer fractions of the sample and were accordingly discarded when one of the coarser particle size fractions (i.e., 60-80 or 80-100) was selected as a representative sample. Furthermore, it was discovered that, when these woods were comminuted by the various methods available at that time, the greatest proportion of these would pass the 100 mesh sieve, and that it was not difficult to treat the wood so that all of a given sample would pass through this sieve.

In view of this earlier work (4, 5), the method of preparation of a wood sample for analysis adopted in this laboratory aimed essentially at the inclusion of the whole of a given sample and at the avoidance of loss of any fine material which, in certain cases, as mentioned above, had been proved to be rich in extraneous material. (In the following discussion the extraneous material will, for convenience, be referred to as "kino"). The major part of these analyses was, however, devoted to woods rich in kino, e.g., jarrah (*E. marginata,* Sm.) and red mahogany (*E. resinifera,* Sm.), and the procedure adopted in the preparation of the sample was to grind or mill the wood until the whole was fine enough to pass through a 100 mesh sieve and no portion was rejected. The use of this procedure has been criticized by Campbell and Bryant (3) following their work on the preparation of wood samples from jarrah. The main points brought forward by these authors indicated that there could be produced from a sample of jarrah, a 60–80 fraction which would satisfactorily represent the whole of the wood, and, further, that fine comminution either caused degradation of the wood or permitted degradation during subsequent chemical analysis. The first of these points was based on evidence which in the light of data presented here may not be regarded as legitimate. The second point was supported by sufficiently well-founded evidence and threw suspicion on the condition of the wood sample and significance of its analyses as obtained in this laboratory. Accordingly, the whole question of preparation of wood samples for analysis, with particular reference to Australian woods, has been reconsidered in the present investigation.

Concerning the claim put forward by Campbell and Bryant (3), namely, that there could be prepared from jarrah a 60–80 mesh fraction which would satisfactorily represent the whole of the wood, the opportunity was taken during the visit of one of the authors (W.E.C.) to the Forest Products Research Laboratory, Princes Risborough, in 1937, to investigate this matter further in collaboration with W. G. Campbell. A short investigation using the equipment then employed at that laboratory was carried out and, through the courtesy of the Director, the results are presented below.

In order to prepare 60–80 mesh fractions, a sample of jarrah was treated in two ways. (*a*) One section was rasped by hand and sieved through a 60 mesh screen. The material passing the 60 mesh screen was retained as such (sample 1). The material greater in size than 60 mesh was ground in a coffee mill and sieved through 60 and 80 mesh screens to give 60–80 mesh (sample 2) and 80— mesh (sample 3) fractions. (*b*) The remainder of the wood was converted to sawdust using a 12-in. circular rip saw, the yields expressed as percentages of converted wood, being 17.1 per cent. —60 mesh and 47.2 per cent. 60— mesh with a loss of 35.7 per cent. The 60— sawdust was sieved through 60, 80, and 100 mesh sieves to give 60–80 (sample 4), 80–100 (sample 5), and 100— (sample 6) mesh fractions.

The six samples obtained were weighed and analysed, the determinations carried out being solubility in alcohol-benzene, solubility in 0.5 per cent. sodium hydroxide, apparent lignin, lignin after extraction with 0.5 per cent. sodium hydroxide, and total xylan (6). The results are set out in Table 1.

TABLE 1.

Analyses are Stated as Per Cent. Original Oven-dry Wood.

Method of Preparation.	Screen Fraction and Sample No.	Oven-Dry Weight.	Solubility in Alc.-Benz.	Solubility in 0.5 per cent. Sodium Hydroxide.	Apparent Lignin.	Lignin after Extraction with 0.5 per cent. Sodium Hydroxide.	Total Xylan.
		(g.)	%	%	%	%	%
60 — raspings as received	60 — (1)	22·00	2·6	29·4	41·7	22·0	10·4
— 60 raspings ground in coffee mill	60–80 (2)	24·16	2·0	19·6	36·9	24·9	11·0
	80 — (3)	20·54	2·3	26·5	39·7	22·8	10·5
Total raspings	Mean wt. analysis	66·70 +0·45* —— 67·15	2·3	25·0	39·4	23·3	10·5
Sawdust (47·2 per cent of wood)	60–80 (4)	55·7	2·1	21·3	38·4	24·7	11·2
	80–100 (5)	36·3	2·3	20·8	37·3	24·4	11·1
	100 — (6)	148·2	2·5	22·9	38·0	23·8	10·8
	Mean wt. analysis	240·2	2·4	22·2	38·0	24·1	10·9

* Wt. of —60 mesh material after coffee mill grinding (not analysed).

Comparing the calculated mean weight analyses of the wood prepared by the two methods, it is seen that there is not good agreement in analytical data between two originally similar samples. This is clearly due to the loss of a very large portion of material (35.7 per cent.) in converting to sawdust, a great deal of the loss being due to breakdown of kino and wood to a fine powder which could not be collected. The sawdust, as analysed, represents a material partially purified by removal of kino. On the other hand, there is only a very small amount of material (0.45 g.) discarded from the raspings, and the mean weight analysis of this sample should closely represent the original wood.

The two 60–80 mesh fractions (sample 2 and 4) show close agreement in alcohol-benzene solubility, xylan, and lignin (after extraction with 0.5 per cent. sodium hydroxide), but there is considerable difference in the amount of extractive material as shown by solubility in 0.5 per cent. sodium hydroxide. Further, neither of these 60–80 mesh fractions agrees in any detail with the calculated mean weight analysis for the

whole sample as determined from the total raspings. It is apparent from this brief survey that this method of selecting a 60–80 mesh fraction as representative of a sample of jarrah is not adequate.

It is clear that still further investigation is required to determine a method for obtaining a material which is suitable for analysis and actually representative of a wood such as jarrah. Consequently, the results of a more detailed investigation are outlined below.

2. Experimental.

The timbers used for the investigation were jarrah and mountain ash (*E. regnans* F.v.M.), the former being chosen as representative of timbers rich in extraneous material and the latter as representative of the paper-making group. Sound blocks, free from gum pockets or other defects, were chosen, and these were broken down on the circular saw into sticks approximately 2 in. x 2 in. x 12 in. The sticks were cut across the grain on a mitre machine into slices approximately 1-16th in. thick, hand crumbled, and allowed to dry. After thorough mixing the samples were stored in dust-proof containers.

Preliminary trials using a Christy and Norris mill* and a standard laboratory Wiley mill† were carried out in order to determine actual losses during comminution, and the degree of fineness of the material obtained. Of these mills, the first is a high-speed type (6,000 revs. per min.) fitted with beater cross-arms, and the original slotted screen supplied with the mill was replaced by a curved blank plate across the base of the mill to make the housing continuous. The wood sample remained in the sphere of the beater arms until fine enough to be carried by the air stream through a hole in the side of the mill housing. With this arrangement approximately 80 per cent. of the sample was fine enough to pass through a 100 mesh sieve after one run, and, after four or five millings of the oversize material 93 to 94 per cent. recoveries on 100 g. samples were obtained as "all through 100 mesh." During this process moisture losses of 1.0 to 2.5 per cent. occurred, and consequently all yields are calculated on an oven-dry basis.

The second mill has essentially a cutting action and was operated at 745 revs. per minute. When used with the 0.5 mm. screen (approx. 60 mesh) it was found that approximately 95 per cent. of the material would pass through a 60 mesh screen after 30 minutes milling. The oversize material was returned once to the mill for further treatment. Recoveries obtained with the two species investigated were 96 to 98 per cent. of 60— mesh material from 100 g. samples. Moisture losses were of the order of 0.1 to 0.2 per cent. and have been neglected in calculating yields.

Using a 1 mm. screen on the Wiley mill it was found that, after one milling, 40 to 50 per cent. of the sample remained greater than 60 mesh in size. It was difficult to reduce the amount of this oversize fraction except by the use of a finer screen. By first milling the sample and using the 1 mm. screen, and then milling the —60 mesh fraction using the 0.5 mm. screen, it was found possible to obtain increased yields of 60–80 mesh fraction, the amount being 40 to 55 per cent. of the sample with both woods investigated.

* See Baird and Tatlock, Catalogue 1928, Vol. 1., No. C.1961

† See Arthur H. Thomas Co., Catalogue 1931, p. 277.

Replication of the yields of the intermediate fractions (60–80, 80–100, 100—) from the Wiley mill was satisfactory when the millings were carried out consecutively or nearly so. Otherwise a tendency to an increase in the amount of fines (100— fraction) could be detected with blunting of the knives. However, with flat ground knives which had had some use, steady yields of the intermediate fractions were obtained if the material was milled using first the 1 mm. screen and then the 0.5 mm. screen.

Sieving tests were carried out on the 100— mesh fractions obtained from each of the mills in order to determine the distribution of particle size in the fine fractions. The results are given in Table 2.

Table 2.—Distribution of Particle Size in the 100— Fractions from the C. & N. and Wiley Mills.

Expressed as Percentages of Total Sample.

Fraction.	C. & N. Mill.		Wiley Mill.	
	Mountain ash.	Jarrah.	Mountain ash.	Jarrah.
100–120	6·2	6·1	12·7	12·9
120–160	12·9	8·0	9·4	11·6
160–240	34·3	11·9	8·1	15·6
240—	46·0	72·7	7·4	8·0

Details of the actual yields of the samples prepared for analysis are set out in Table 3. It should be noted that in the case of each of the species investigated two wood samples were taken. These have been designated A and B.

Mountain Ash.— Three 100 g. matched portions of A were taken for comminution in the Wiley mill. The first was passed through the 0.5 mm. screen, and the product was sieved to give 60–80, 80–100, 100— mesh fractions (samples 1, 2, 3). The second was similarly milled, but was retained as "all through 60 mesh" (sample 4). The third was milled using the 1 mm. screen and the 60–80 mesh fraction (Sample 5) was selected.

Three 100 g. matched portions of B were taken. The first was treated in the Wiley mill to provide an "all through 60 mesh" sample (sample 6). The second was comminuted to "all through 100 mesh" by means of the C. & N. mill (sample 7), the mill being cooled throughout by means of a stream of carbon dioxide from a cylinder. The third was similarly comminuted in the C. & N. mill but without cooling (sample 8).

Jarrah.—Five 100 g. matched portions of A were taken for treatment in the Wiley mill. The first was passed through the 0.5 mm. screen and fractionated (samples 9, 10, 11). The second was milled similarly but was retained as "all through 60 mesh" (sample 12). The third was passed through the 1 mm. screen, the 60–80 mesh fraction (sample 13) being selected. The fourth was passed first through the

TABLE 3.—DETAILS OF COMMINUTIONS CARRIED OUT IN WILEY AND C. & N. MILLS.

100 g. Air-dry Samples taken in Each Case.

Wood.	Mill.	Screen Used in Mill.	Fraction or Sample.	Yield of Fraction or Sample.	Loss During Milling.	Sample No.
				%	%	
Mountain ash (A)	Wiley ..	0·5 mm.	60–80	25·6	2·7	1
	..	..	80–100	31·1	..	2
	..	..	100—	40·6	..	3
	Wiley ..	0·5 mm.	60—	97·7	2·3	4
	Wiley ..	1 mm.	60–80	26·2	1·4	5
Mountain ash (B)	Wiley ..	0·5 mm.	60—	98·2	1·8	6
	C. & N. ..	blank plate	100—	93·2	6·8	7
	C. & N. ..	blank plate	100—	94·5	5·5	8
Jarrah (A) ..	Wiley ..	0·5 mm.	60–80	10·4	3·1	9
	..	..	80–100	26·3	..	10
	..	..	100—	60·2	..	11
	Wiley ..	0·5 mm.	60—	97·4	2·6	12
	Wiley ..	1 mm.	60–80	29·6	1·2	13
	Wiley ..	1 mm. followed by 0·5 mm.	60–80	43·7	3·6	14
			80–100	18·8	..	15
			100—	33·9	..	16
	Wiley ..	0·5 mm.	60—	97·8	2·2	17
Jarrah (B) ..	Wiley ..	0·5 mm.	60—	96·6	3·4	18
	C. & N. ..	blank plate	100—	95·1	4.9	19

1.0 mm. screen and sieved. The —60 mesh material was then passed through the 0.5 mm. screen and sieved further. The three fractions, 60–80, 80–100, 100— mesh (samples 14, 15, 16) were then retained as separate samples. The fifth was milled to pass through the 0.5 mm. screen and retained as "all through 60 mesh" (sample 17).

Two 100 g. matched portions of B were taken. One was treated in the Wiley mill using the 0.5 mm. screen and was not fractionated (sample 18). The other was comminuted to "all through 100 mesh" in the C. & N. mill without cooling (sample 19). In addition, two matched portions (100 g.) of 60–80 mesh mountain ash (A) were taken from a bulk supply. Of these, one (sample 20) was kept intact, while the other (sample 21) was comminuted further in the C. & N. mill. The —100 mesh material was returned to the mill after each run, two runs being carried out. The final composition of the sample was, 60–100 fraction, 11.8 per cent., 100— fraction, 83.3 per cent., loss 4.9 per cent. The whole was then re-mixed as one sample.

Each of the samples (1 to 21), prepared as described above, was submitted to chemical analysis, the determinations carried out being total xylan* (6), "apparent lignin," Cross & Bevan cellulose, and xylan in cellulose (6). The "apparent lignin" determination was carried out without pre-treatment of the wood samples. The results are set out in Tables 4 to 8.

3. Discussion.

Preliminary milling trials using both the Christy and Norris mill and the Wiley mill showed that, with the former, losses amounted to 5 per cent. of the sample, while with the latter they were smaller and varied from 1 to 3 per cent., these figures being obtained for 100 g. samples. These losses have been accepted as being sufficiently low to have no serious effect on subsequent analyses even should the amount lost contain a preponderence of any one constituent.

The figures given in Table 2 indicate clearly the enormous difference in the amount of "fines" produced by the two mills. Whereas the 240— mesh fraction of the wood sample prepared in the Wiley mill is in both cases the smallest of the four, it is by far the largest from the C. & N. mill. In addition the 100— mesh material from the C. & N. mill represents the whole of the sample, whereas only about 40 per cent. of the material from the Wiley mill will pass through a 100 mesh sieve.

Considering first this marked difference in particle size of the material produced by two mills, it is desirable to compare the analyses of matched samples prepared in each (Table 4).

Samples 6, 7, 8 of mountain ash show little difference in total xylan or apparent lignin content. However, the finer material is considerably lower (2.6 per cent.) in C. & B. cellulose content, and the difference is also shown partially in xylan-in-cellulose. In the case of jarrah (samples 18 and 19) there is good agreement in total xylan and apparent lignin, and the C. & B. cellulose is very little lower for the finer sample. The difference in cellulose is not as large as in the case of mountain ash, due possibly to the intrinsic nature of jarrah cellulose.

Referring again to samples 7 and 8, no positive result of cooling the mill by a current of carbon dioxide can be observed. There is good agreement in total xylan and apparent lignin content of the two samples. The figure shown for cellulose was obtained by mixing the two samples and is quoted since it was determined at the same time as the rest of the work was carried out. However, previous analyses (not shown) indicated a difference of no more than 0.3 per cent. between the C. & B. cellulose contents of the two samples. It is difficult to draw any conclusion from this result since it is not known whether the cooling was effective. It was possible only to read the temperature of the outside of the mill housing, and, although this was controlled, it does not necessarily follow that there was any considerable decrease in the heating effect produced by the action of the beater arms on the wood particles.

The analysis data of matched samples from the Wiley and C. & N. mill (Table 4) establish beyond doubt that serious degradation of the cellulose in subsequent analysis occurs through finer comminution in

* Furfural-yielding substances determined as xylan for convenience.

TABLE 4.

Species.	Sample No.	Mesh and Mill.	Total Xylan.	Lignin.	C. & B. Cellulose.	Xylan in C. & B. Cellulose. Percentage of Wood.
			%	%	%	
Mountain ash (B) ..	6	60— Wiley	15·8	24·3	57·5	10·7
	7	100— C. & N.	15·7	24·6	54·9	9·0
	8	100— C. & N.	15·6	24·5		
Jarrah (B)	18	60— Wiley	8·5	39·3	41·0	5·5
	19	100— C. & N.	8·6	39·3	40·6	5·4

the latter. It is probable, then, that the fine material (through 100 mesh) in the 60 — mesh sample from the Wiley mill has itself been reduced to a state such as to permit degradation during analysis. The extent of this and its effect on the analysis of the whole sample has been investigated by analysing separately the three major fractions (60–80, 80–100, 100— mesh). The results of these analyses for mountain ash are given in Table 5, and, where fractions were taken, a mean weight analysis of the whole sample has been calculated.

The analyses of samples 1 to 3 show little evidence, from total xylan and lignin content, of segregation of extraneous material into the finer fraction (sample 3). In addition, there is excellent agreement between the calculated mean composition of this sample and the analysis of the corresponding "all through 60 mesh" sample 4. Hence it is evident that the lower cellulose content of the 100— mesh fraction (sample 3) as compared with the 60–80 mesh fraction (sample 1) is due to degradation or loss of the fine material during analysis. The effect (approx. 1 per cent.) is not so marked as in the case of the fine product from the C. & N. mill and is not shown in the xylan-in-cellulose content. The calculated mean cellulose content of the whole sample (58.3 per cent.) is slightly lower than that of the 60–80 mesh fraction (59.0 per cent.) and this decrease, although probably not highly significant, could be attributed to degradation during the analysis of the fines. Hence the 60–80 mesh fraction gives a truer representation of the original sample of mountain ash than does the whole 60— mesh sample. Nevertheless, the difference is slight and for practical purposes it is probable that either sample could be accepted.

A further test of the effects of fine comminution on subsequent analyses was made by comparing two 60–80 mesh samples (20, 21). One of these (sample 20) was analysed as such, while the other (sample 21) was comminuted as finely as possible in the C. & N. mill. The

TABLE 5.

Species.	Sample No.	Mesh	Total Xylan.	Lignin.	C. & B. Cellulose.	Xylan in C. & B. Cellulose. Percentage of Wood.
			%	%	%	
Mountain ash (A)	1	60–80	17·7	24·2	59·0	12·2
	2	80–100	17·6	24·1	59·0	12·4
	3	100—	17·5	24·3	57·4	12·2
	Mean weight analysis calculated from 1, 2, 3	..	17·6	24·2	58·3	12·3
	4	60—	17·6	24·2	58·0	12·2
Mountain ash (A)	20	60–80	17·7	24·5	59·2	12·5
	21	60— (from C. & N. mill.)	17·8	24·3	58·3	11·9

analyses (Table 5) show good agreement in total xylan and apparent lignin content, but reveal a decrease (0.9 per cent.) in cellulose content as the result of the finer comminution. It is apparent, then, that again a diminution in particle size has resulted in a decrease in cellulose during subsequent analysis, although the effect is not so marked as in the case of samples 6, 7 and 8.

The results of the analyses (Table 6) of samples of jarrah (A) from the Wiley mill reveal a situation entirely different from that found for mountain ash.

Inspection of the data for the three fractions 9, 10, 11 shows immediately a pronounced decrease in total xylan and C. & B. cellulose with a corresponding increase in apparent lignin. This effect is even more marked in the case of the fractions 14, 15, 16 where the method of comminution was altered in order to reduce the amount of the 100— fraction (33.9 per cent.). It is clear that in this case the fine fraction contains a much greater percentage of kino than is the case when more severe milling permits a larger amount of the wood to pass into the fine fraction. Comparison of jarrah samples 18, 19 (Table 4) prepared in the Wiley and C. & N. mills respectively, showed clearly that the extremely drastic action of the latter caused only a slight reduction (0.4 per cent.) in C. & B. cellulose. Consequently, reduction of cellulose content in one case of 4.7 per cent. and in the other of 7.7 per cent., with only an accompanying small reduction in xylan-in-cellulose, can be attributed almost exclusively to dilution by means of kino. Further, since the presence of fines, in the case of jarrah, does not seriously affect

TABLE 6.

Species	Sample No.	Mesh.	Total Xylan.	Lignin.	C. & B. Cellulose.	Xylan in C. & B. Cellulose. Percentage of Wood.
			%	%	%	
Jarrah (A) ..	9	60–80	8·5	42·4	42·9	4·7
	10	80–100	8·7	42·2	42·8	4·5
	11	100–	7·2	43·6	38·2	4·2
	Mean weight analysis calculated from 9, 10, 11.	..	7·7	43·1	39·9	4·3
	12	60–	7·7	43·0	39·7	4·2
Jarrah (A) ..	14	60–80	8·6	43·7	42·3	4·7
	15	80–100	8·6	43·5	42·3	4·8
	16	100–	6·5	47·0	34·6	4·4
	Mean weight analysis calculated from 14, 15, 16.	..	7·8	44·8	39·6	4·6
	17	60–	7·8	44·6	39·5	4·4

the C. & B. cellulose content, the result found for the "all through 60 mesh" sample will represent, with considerable accuracy, the original state of the wood sample. This conclusion is borne out by the excellent agreement between the mean composition calculated for each of the two sets of fractions and the corresponding "all through 60 mesh" samples (12, 17).

For the samples of jarrah investigated and for the milling equipment used, it is proved that rejection of the fines and selection of either the 60–80 or 80–100 mesh fraction will lead to serious errors in subsequent analysis. The only satisfactory method of preparing the wood sample is to utilize milling equipment with the mildest possible action on the wood consistent with its reduction to particle size small enough for analysis, and to avoid the rejection of any portion of the material.

In connection with this work an interesting point has arisen. The analyses carried out (total xylan and apparent lignin) were originally selected as being those which would give results independent of particle size and would thus give a measure of the segregation of kino into the fine fraction. It immediately became apparent, however, that the lignin determination would not suffice for this purpose since the kino is not completely insoluble in sulphuric acid and a greater amount is dissolved from the fine fraction than from the others.

In addition, the xylan determination did not provide a satisfactory measure of the amount of segregation. If the cellulose content of either of the 60–80 mesh samples 9 or 14 is reduced in the ratio of the xylan contents of the 60–80 and 100— mesh fractions,

$$\left(\text{i.e., } 42.9 \times \frac{7.2}{8.5} = 36.4 \text{ or } 42.3 \times \frac{6.5}{8.6} = 32.0\right)$$

it is clear that, on this basis, the cellulose content should be lower than actually found for the 100— mesh fraction. The only solution to such an anomaly is that the xylan value is suppressed by retention of furfural or furfural-yielding materials by the excessive amount of kino present. Some evidence in favour of this supposition is given in Table 7.

TABLE 7.

Species.	Pre-treatment.	Total Xylan. Percentage of Wood.
Jarrah (C) ..	Nil	8·6
	Extd. alc., alc.-benz., ether	8·7
	Extd. alc., alc.-benz., ether, hot water	8·9
Jarrah (D) ..	Nil	8·9
	Extd. hot water	9·4
	Extd. $\frac{N}{25}$ NaOH	8·6
Mountain ash	Nil	17·6
	0·44 g. kino added	17·0

A sample of jarrah (C) shows a small but progressive increase in total xylan content on extraction with organic solvents and with hot water, even though the latter might be expected to exert a mild hydrolytic effect on the xylan. The second sample of jarrah (D) showed a similar increase in xylan content on extraction with hot water, but a decrease occurred on extraction with dilute alkali. Evidently the latter caused hydrolysis or solution of a small portion of the furfural-yielding material. In addition, it was found that the addition of 0.44 g. of kino from a gum pocket of jarrah to a sample of mountain ash caused a marked depression in total xylan content. A blank determination on the sample of kino showed the absence of furfural-yielding groups.

Finally, a comparison has been made of the replication obtained with 60-80 mesh fractions prepared in the Wiley mill. In the case of mountain ash (samples 1 and 5) one sample was prepared using the 0.5 mm. screen in the mill and the other using the 1 mm. screen. From jarrah, three samples (9, 13, 14) were prepared, one using the 0.5 mm. screen, the second using the 1 mm. screen, and the third using the 1 mm. screen followed by the 0.5 mm. screen. The results of the analyses are given in Table 8.

TABLE 8.

Species.	Sample No.	Screen used in mill.	Total Xylan.	Lignin.	C. & B. Cellulose.	Xylan in C. & B. Cellulose. Percentage of Wood.
			%	%	%	
Mountain ash (A)	1	0·5 mm	17·7	24·2	59·0	12·2
	5	1 mm.	17·7	24·1	59·6	13·3
Jarrah (A) ..	9	0·5 mm.	8·5	42·4	42·9	4·7
	13	1 mm.	8·5	42·6	42·2	4·6
	14	1 mm. followed by 0·5 mm.	8·6	43·7	42·3	4·7

In the case of mountain ash (samples 1 and 5) agreement between the analytical figures is satisfactory, with the exception that the cellulose content of the sample prepared with the 1 mm. screen is 0.6 per cent. higher, and this increase is more than reflected in the xylan in cellulose. Similarly, the jarrah samples (9, 13, 14) agree closely, with the exception that the sample prepared using the 0.5 mm. screen is 0.6 per cent. higher in cellulose than the other two. Also sample 14 is approximately 1 per cent. higher in lignin than the other two. No explanation of these discrepancies can be given although it is possible that in the case of sample 5 complete delignification was not achieved. This would conceivably cause higher xylan in cellulose figures, the xylan being retained in association with the lignin. It is doubtful, however, whether differences in C. & B. cellulose can be considered as beyond the limit of experimental error.

As a result of the work outlined above, the general practice in this laboratory of taking an "all through 100 mesh" sample for jarrah has been altered to substitute "all through 60 mesh" material. Such an alteration might have introduced a complication in regard to handling a wider range of particle size. However, little difficulty has been encountered in practice beyond the necessity for a little extra care in observing the end-point of the cellulose determination.

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A Constant Moisture Content Room for Timber.

*By W. L. Greenhill, M.E., Dip.Sc.**

Summary.

A description is given of the construction and of the method of conditioning and controlling a small room designed to bring timber to a definite constant moisture content. In the room no attempt is made to maintain either a constant temperature or a constant relative humidity, but rather to maintain the correct relation between the two to give a constant equilibrium moisture content. The swelling or shrinking of a sensitive wood element with moisture content change is used to control the conditions. If the air be too dry, suitable humidification is brought into play; if it be too wet, the relative humidity is lowered simply by heating. In this manner the need for either cooling or dehumidifying units is avoided.

1. Introduction.

In many research laboratories and also in different phases of the commercial production of timber products, paper, textiles, cereals, and many other hygroscopic materials, conditioning rooms are frequently required either to bring material to a constant moisture condition or to hold it at a constant condition for testing, ageing, or prior to despatch. The room described in this article was designed for conditioning timber for mechanical testing, but the principle involved is not necessarily confined to this material.

The usual method of obtaining suitable conditions of the atmosphere in a room to bring timber to a predetermined moisture content is to maintain both a constant temperature and a constant relative humidity. This is done by means of a thermostat and a humidistat or a wet and dry bulb controller, together with suitable heating, cooling, humidifying, and dehumidifying equipment. While heating and humidifying can be accomplished relatively simply and cheaply, expensive equipment is necessary for cooling and dehumidifying. In the room described, no attempt is made to maintain either a constant temperature or a constant relative humidity but rather to maintain the correct relation between the two to give constant equilibrium-moisture-content (E.M.C.) conditions. If the E.M.C. conditions in the room need to be reduced, this is accomplished simply by raising the temperature of the air. This procedure is effective in two ways; an increase in temperature would lower the E.M.C. conditions at the same relative humidity, but actually the increase in temperature also lowers the relative humidity. On the other hand, if the conditions are too dry, they are adjusted by suitable humidification. It will be seen that with such a method of control the need for either cooling or dehumidification equipment is avoided. Although no temperature control is necessary, a thermostat has been installed to prevent the room temperature falling below 70°F., as at winter temperatures the rate of transfusion of moisture through wood is very slow, unduly prolonging the time required to condition the timber.

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2. Details of Room and Conditioning Units.

The room is approximately 21 feet long, $7\frac{1}{2}$ feet wide, and 9 feet high. It is located in the basement of the Forest Products Laboratory where it is fitted in, as conveniently as possible, with the existing pillars, beams, and service piping. The design has necessarily been modified to suit the particular location. The room is closed at one end by a main wall of the building in which windows are conveniently located, and at the other end there are double doors. The side walls are constructed of a single layer of $\frac{1}{2}$-in. fibreboard on 3-in. x 2-in. studs. Both sides of the room are fitted internally with racks about 2 feet wide for holding timber samples; there is thus a passageway more than 3 feet wide down the centre. The racks are only about 7 feet high and above them is a sub-ceiling, the upper part of the room serving to house the two conditioning units. The general layout of the room is shown in Fig. 1.

The conditioning units are self-contained, the design being indicated in Fig. 2. Air circulation is provided by means of a 15-in. propeller fan directly coupled to a $\frac{1}{4}$-horsepower single-phase electric motor. After passing through the unit the air is divided by suitable ducting and delivered down through the timber racks on the two sides. A water trough in the bottom of the unit serves to provide humidification. The water has a surface area of 18 inches x 8 inches and the trough is fitted with a ball cock to maintain a constant water level and also with an electric strip-type immersion heater. As required, the water is heated until there is sufficient evaporation into the air passing

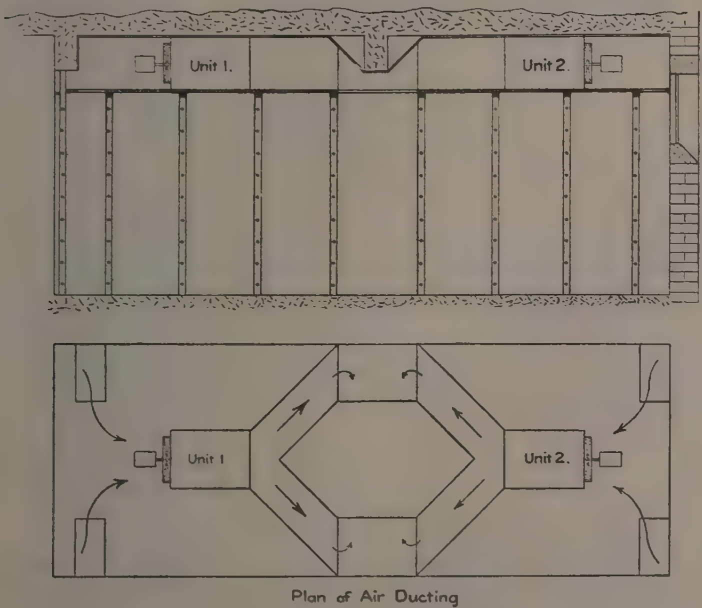

Fig. 1.—Layout of Room and Air Ducting.

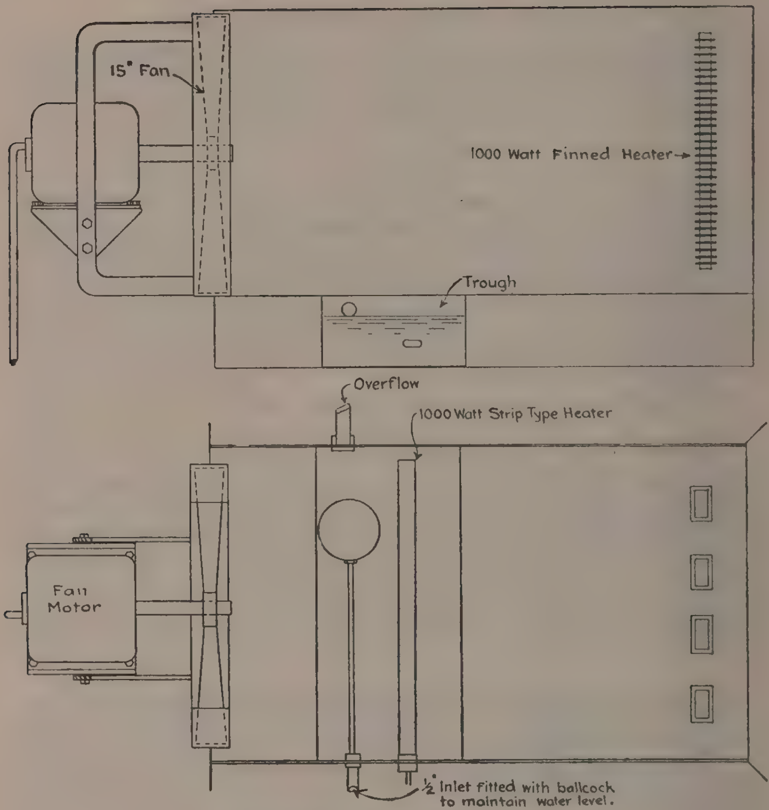

FIG. 2.—The Conditioning Unit.

through the unit. Heating of the air is provided when required by finned electric heaters located at the air exit end of the unit. Both the water heater and the air heaters are rated at approximately one kilowatt.

It might be mentioned that a single unit of the capacity described would be sufficient for a room such as described, under almost all conditions that would be desired in practice. The second unit was desirable in the present case mainly to ensure adequate circulation, a beam of the main building practically dividing the upper part of the room into two.

Measurements of the power consumption of the room operating at a minimum temperature of 70° F. and maintaining an E.M.C. condition of 15 per cent., have given a value of 21 kilowatt-hour units per 24 hours averaged over two weeks in August and September.

The total cost of this room was less than £150. It has now been in continuous operation for about five months and has given a very satisfactory performance, the only trouble experienced being with the adjustment of the ball cocks on the water troughs.

3. Control Equipment.

As the room is designed to maintain a constant E.M.C. condition for timber, it seemed appropriate that the control might be made to depend on the moisture content of a piece of wood in the room. Accordingly, use has been made of a sensitive wood element in which the shrinking or swelling with changing moisture content serves to bring about the necessary corrective operations. There is practically no hysteresis in the relation between moisture content and shrinkage of wood up to about 20 per cent. moisture content, and, provided there are no heavy restraining forces to induce "set," the relation between moisture content and shrinking and swelling remains virtually constant.

The use of wood elements in humidistats is not new either commercially or for laboratory purposes. One of the most sensitive commercial humidistats employs chains of cone fibres, these having five times the extension of hair for the same increase in moisture content. A wood element humidistat is described by Loughborough and Rietz*, and a number of instruments similar to this are in constant use at the Forest Products Laboratory, Madison, United States of America. This instrument can be made extremely sensitive, but because it depends for its action on the tendency of a thin bent piece of wood to straighten out, the amount of power that can be exerted is quite small. Also it is subject to fatigue, especially if used at any but comparatively low temperatures. A more robust but much less sensitive wood element humidistat is described by Knight†. The hygroscopic element in this case is a wood block 2 inches x $1\frac{1}{8}$ inch x $\frac{1}{2}$ inch, and its use is recommended simply for keeping the E.M.C. conditions in a wood store below some pre-selected value by arranging for the swelling of the wood to turn on a heater.

The controller used in the room described is shown in Fig. 3. In an attempt to obtain a wood element which will be reasonably sensitive and at the same time have considerable power, a tube of wood has been chosen. This is about 6 inches long, $\frac{3}{4}$ inch outside diameter, and has walls 1-16th inch thick. It is cut so that the axis of the tube is tangential in the wood (giving a maximum movement with moisture change), and the wood selected, myrtle beech, has a large shrinkage movement and is a good turning timber. To facilitate ready access of the air to the whole area of the wood tube, it is perforated with holes in the side. This wood element actuates directly either one of two micro-switches, according to whether the wood swells or shrinks. The micro-switches operate with a 0.004-in. movement and very little pressure and can handle directly a current of 5 amps at 230 volts A.C. Provision is made for individual adjustment of the settings of the two switches and also to allow for an over-movement of the element without damage occurring.

The controller is located near the centre of one side of the room where the air from the two conditioning units mixes and passes into the timber racks. The controller operates both units simultaneously

* Loughborough, W. K., and Rietz, R. C.—*Instruments* 5: 143-4, June, 1932.

† Knight, R. A. G.—*Wood* 3 (12): 595, Dec., 1938.

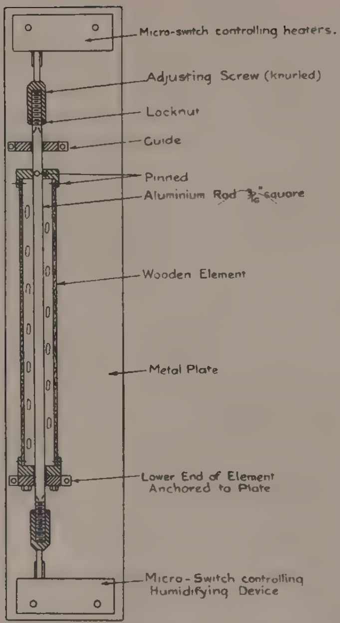

FIG. 3.—Wood element Controller.

through suitable relays. When the air becomes too moist, the wood element increases in moisture content, swells, and thereby switches on the heating equipment which will restore the correct E.M.C. conditions. As the air becomes drier, the wood element shrinks and first switches off the heaters, and then, should the air become too dry and the wood continue to shrink, it will switch on the humidifying equipment. A suitable "floating" position is provided in which neither the humidity nor the heat is turned on.

The E.M.C. condition of the room is measured by weighing carefully prepared strips of thin veneer, the oven-dry weights of which have been calculated. Variations are of the order of only 1 or 2 tenths of 1 per cent. moisture content.

A Note on the Measurement of Relative Humidity with Reference to Paper-Testing Rooms.

*By W. L. Greenhill, M.E., Dip.Sc.**

Summary

Although the wet and dry bulb hygrometer is undoubtedly the simplest practical instrument for measuring the relative humidity of the air, certain precautions must be taken in the use of this equipment if accurate results are required. Apart from the question of a suitable wick and water supply, there is the need for a definite air velocity past the wet bulb and for the use of a suitable hygrometric formula for converting the wet and dry bulb readings into relative humidity. Three series of tests have been made in a paper-testing room at approximately 21°C. and 65 per cent. relative humidity. These tests compare wet bulb readings at different air velocities and also wet and dry bulb readings with dew point determinations and gravimetric determinations respectively. As a result, it is concluded that the most suitable form of hygrometer for laboratory use is that in which the wet bulb is ventilated by a clockwork fan. A chart is included for the conversion of wet and dry bulb readings so obtained to relative humidities.

1. Introduction.

According to the specifications formulated by the Technical Section of the Paper Makers' Association of Great Britain and Ireland (2), all test samples of paper are to be conditioned and tested in an atmosphere maintained at 65 per cent. relative humidity and 65° to 70°F. (18.3° to 21.1°C.). A tolerance of ± 2 per cent. in relative humidity is permissible. It is further stated that the relative humidity of the conditioning atmosphere shall be determined by means of wet and dry bulb thermometers placed in an air current of velocity of at least three metres per second, and that suitable tables which are computed for thermometers ventilated in a draught of three metres per second velocity must be used.

In practice, an air velocity past the wet bulb of three metres per second cannot always be obtained conveniently, and means are seldom available for measuring this air velocity. Another difficulty is that with most sets of hygrometric tables, the velocity for which the tables have been computed is not stated; as will be shown later, quite appreciable errors may be introduced by using tables not suited to the conditions of measurement of the wet and dry bulb temperatures. Finally, it might be pointed out that some discrepancies between different hygrometric charts are due to confusion in the definition of relative humidity. Correctly defined, relative humidity is the ratio of the actual partial pressure of the water vapour in the air to the saturation pressure at the dry bulb temperature. This is not exactly equal to the ratio of the weight of vapour per pound of dry air to the weight of saturated vapour per pound of dry air, although the latter definition is frequently given. The error is usually small, especially at temperatures below

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70°F., but at higher temperatures it may become quite appreciable. The extent of the error at conditions approximating those maintained in paper-testing rooms is indicated in an appendix.

Some experience in the measurement of relative humidity by the wet and dry bulb hygrometer has been obtained in the paper-testing room of the Division of Forest Products, and the following notes may be of value to anyone confronted with such a problem.

2. The Wet and Dry Bulb Hygrometer.

The theory underlying the use of the wet and dry bulb hygrometer for measuring relative humidity is discussed at length by Skinner (3) and details of the practical application of the method are fully considered by Carson and Worthington (1). Undoubtedly one of the most important factors affecting the readings obtained, while at the same time probably that most often neglected, is the ventilation of the wet bulb. Several different devices are used to ensure ventilation, but the degree of ventilation varies greatly, and there are corresponding variations in the wet bulb readings.

In the sling psychrometer, ventilation is obtained by whirling the thermometers by hand. In this way a relative velocity with respect to the air of at least three metres per second can readily be obtained, and above this velocity the effect on the wet bulb reading is of no practical significance. The use of this arrangement in a small room well filled with testing equipment has difficulties, however, apart from the fact that the thermometers must be brought to rest before they can be read. A much more convenient type of hygrometer for laboratory purposes is that in which a current of air is drawn over the thermometer bulbs by a clockwork operated fan.

3. Experimental.

In the hygrometer used in the series of tests to be described, ventilation of the wet bulb was obtained by means of a clockwork fan. A second hygrometer was set up in front of an office fan which provided an air circulation past the thermometer bulbs, as measured by an anemometer, of approximately five metres per second. In both hygrometers particular care was taken to use suitable wicks and to ensure an adequate supply of distilled water to them.

For purposes of comparison, relative humidity measurements were also made by means of dew-point equipment and by a gravimetric method. The dew-point apparatus used had a very thin highly polished flat silver mirror which was gradually cooled by circulating water. Dew formation was indicated by photoelectric means, the presence of dew reducing the amount of light reflected from the mirror. The whole apparatus was well protected from any influence of the observer. Such equipment enables dew points to be obtained with a much greater degree of accuracy than is possible in more common arrangements. The gravimetric method employed is described by Skinner (3).

Measurements were made to compare:—

(*a*) Readings of the clockwork-fan hygrometer with those of the hygrometer ventilated by the office fan.

(*b*) Relative humidity values obtained by wet and dry bulb hygrometers, using various formulae, and by the dew-point apparatus.

(*c*) Relative humidity values obtained by the wet and dry bulb hygrometers, using various formulae, and by the gravimetric method.

4. Results.

(a) Comparison of the Two Ventilated Hygrometers.

The thermometers were first carefully checked against each other before the wet bulbs were allowed to become wet. It was found that all four instruments gave the same reading to the nearest 0.1°C.—the limit of accuracy to which readings were taken. The two sets of wet and dry bulbs were then mounted in position and allowed to become steady before readings were taken. As the result of some twenty sets of readings taken on the four thermometers at conditions of approximately 65 per cent. relative humidity and 21.5°C., it was found that the wet bulb depression of the hygrometer ventilated by the office fan was consistently 0.3°C. greater than that of the hygrometer ventilated with the clockwork fan.

(b) Comparison of Wet and Dry Bulb Hygrometers with Dew-point Apparatus.

The results of twelve independent tests are summarized in Table 1. Wet and dry bulb readings were made only on the clockwork-fan-ventilated hygrometer, but humidities have also been calculated for a wet bulb temperature 0.3°C. lower than that obtained, it being estimated that this would correspond to the reading of a wet bulb in air at a velocity of five metres per second. The barometric pressure at the time of the tests was approximately 750 mm.

(c) Comparison of Wet and Dry Bulb Hygrometers with Gravimetric Method.

Two separate tests were made, the gravimetric equipment being set up and manipulated by the Wood Chemistry Section. Both tests lasted approximately one hour. The wet and dry bulb readings were taken on the clockwork-fan hygrometer every minute during the tests, and the average of these readings was used for calculation purposes. The results are given in Table 2, the relative humidities being calculated by the various formulae as in (*b*).

5. Discussion of Results.

An examination of the results shows that the use of formula No. 4 (Pernter, air speeds from 1 to 1.5 metres per second), as applied to the wet and dry bulb readings obtained with the clockwork-fan hygrometer, gives results closely in agreement with those obtained by the dew-point and gravimetric methods. The results estimated for the faster circulation are in closest agreement with those obtained by the dew-point and gravimetric methods when either formula No. 2 (Ferrel), or No. 5 (Pernter, air speeds above 2.5 metres per second), are used.

TABLE 1.—COMPARISON OF WET AND DRY BULB HYGROMETERS WITH DEW-POINT APPARATUS.

Test.	Dew Point, °C.	Relative Humidity from Dew Point.	Clockwork-fan Hygrometer.						
			Dry Bulb, °C.	Wet Bulb, °C.	Relative Humidity.				
					(1)	(2)	(3)	(4)	(5)
1 ..	14·9	65·7	21·6	17·6	65·8	67·7	64·2	65·2	67·6
2 ..	15·2	66·5	21·7	17·8	66·6	68·6	65·0	66·2	68·4
3 ..	13·7	62·3	21·2	17·1	64·6	66·7	63·4	64·0	66·5
4 ..	14·8	65·0	21·7	17·7	66·0	68·0	64·2	65·6	67·7
..	15·1	65·6	21·8	17·9	66·7	68·7	65·0	66·2	68·4
6 ..	15·4	66·5	21·9	18·0	66·8	68·6	65·0	66·2	68·4
7 ..	14·7	66·0	21·3	17·4	66·3	68·2	65·0	65·7	68·0
8 ..	14·5	64·3	21·45	17·5	65·6	67·6	64·6	65·1	67·3
9 ..	14·8	65·7	21·5	17·5	65·7	67·6	64·2	65·1	67·3
10 ..	14·8	65·3	21·6	17·6	65·8	67·6	64·2	65·3	67·5
11 ..	15·0	64·8	21·9	17·8	65·2	67·1	63·7	64·6	67·0
12 ..	15·1	64·8	21·95	17·9	65·3	67·2	63·8	64·8	67·0
Average ..	14·9	65·2	21·6	17·7	65·9	67·8	64·3	65·3	67·6

Test.	Dew Point, °C.	Relative Humidity from Dew Point.	Hygrometer in Air at Velocity 5 m. per Second.						
			Dry Bulb, °C.	Wet Bulb, °C. (Estimated).	Relative Humidity.				
					(1)	(2)	(3)	(4)	(5)
1 ..	14·9	65·7	21·6	17·3	63·4	65·4	61·8	62·9	65·1
2 ..	15·2	66·5	21·7	17·5	64·2	66·2	62·6	63·7	66·1
3 ..	13·7	62·3	21·2	16·8	62·2	64·4	61·0	61·6	64·2
4 ..	14·8	65·0	21·7	17·4	63·6	65·6	61·8	63·1	65·2
5 ..	15·1	65·6	21·8	17·6	64·4	66·3	62·6	63·8	66·1
6 ..	15·4	66·5	21·9	17·7	64·4	66·3	62·6	63·8	66·1
7 ..	14·7	66·0	21·3	17·1	63·9	65·8	62·6	63·3	65·8
8 ..	14·5	64·3	21·45	17·2	63·4	65·3	62·2	62·7	65·1
9 ..	14·8	65·7	21·5	17·2	63·4	65·3	61·8	62·7	65·1
10 ..	14·8	65·3	21·6	17·3	63·4	65·4	61·8	62·8	65·3
11 ..	15·0	64·8	21·9	17·5	62·8	64·8	61·4	62·2	64·7
12 ..	15·1	64·8	21·95	17·6	63·0	64·9	61·4	62·3	64·7
Average ..	14·9	65·2	21·6	17·4	63·5	65·5	62·0	62·9	65·3

(1) Bureau Central Meteorologique, $P_{dp} = P_w - \cdot 00079B\ (t - t_w)$.
(2) Ferrel (U.S.A.), $P_{dp} = P_w - \cdot 000661B\ (t - t_w)\ (1 + \frac{t - t_w}{873})$. Recommended for speeds of at least 3 metres per second.
(3) Glaisher. Hygrometrical Tables. Taylor and Francis, Red Lion Court, Fleet-street, London.
(4) Pernter. $P_{dp} = P_w - \cdot 0008B\ (t - t_w)\ (1 + \frac{t_w}{610})$. For air speeds from 1 to 1·5 m. per second.
(5) Pernter. $P_{dp} = P_w - \cdot 000656B\ (t - t_w)\ (1 + \frac{t_w}{610})$. For air speeds above 2·5 m. per second.

P_{dp} = vapour pressure at dew point.
P_w = vapour pressure at wet bulb temperature.
B = barometer pressure in mm.
t = dry bulb temperature ° C.
t_w = wet bulb temperature ° C.

TABLE 2.—COMPARISON OF WET AND DRY BULB HYGROMETERS WITH GRAVIMETRIC METHOD.*

Test.	Duration, Minutes.	Relative Humidity by Gravimetric Method.	Clockwork-fan Hygrometer.						
			Average Dry Bulb, °C.	Average Wet Bulb, °C.	Relative Humidity.				
					(1)	(2)	(3)	(4)	(5)
1 ..	63·0	65·5	21·5	17·5	65·6	67·6	64·2	65·1	67·4
2 ..	68·0	64·5	21·5	17·4	64·8	66·8	63·4	64·2	66·7
Average ..	65·5	65·0	21·5	17·45	65·2	67·2	63·8	64·7	67·1

Test.	Duration, Minutes.	Relative Humidity by Gravimetric Method.	Hygrometer in Air at Velocity 5 m. per Second.						
			Average Dry Bulb, °C.	Average Wet Bulb, °C. (Estimated).	Relative Humidity.				
					(1)	(2)	(3)	(4)	(5)
1 ..	63·0	65·5	21·5	17·2	63·3	65·3	61·8	62·7	65·0
2 ..	68·0	64·5	21·5	17·1	62·5	64·6	61·0	61·8	64·4
Average ..	65·5	65·0	21·5	17·15	62·9	65·0	61·4	62·3	64·7

* Footnotes to this table are as below Table 1.

The variability of the relative humidities calculated from the wet and dry bulb readings by different formulae indicates the extent of the errors which may be introduced by using tables unsuited for the particular conditions of the test—errors nearly twice as large as the specified tolerance in conditions.

For measuring relative humidities in small rooms such as those commonly used for paper testing, the most convenient type of instrument is undoubtedly a wet and dry bulb hygrometer with self-contained means, such as a clockwork fan, for providing ventilation of the bulbs. For such an arrangement the Pernter formula for medium air speeds (1 to 1.5 metres per second) appears to give entirely satisfactory results, and its use is recommended. A chart based on this formula for air conditions in the vicinity of 65 per cent. relative humidity and 20°C. is given.

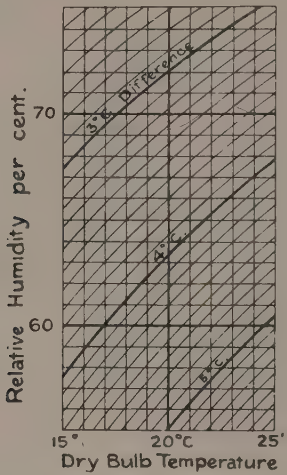
6. References.

1. Carson, F. T., and Worthington, F. V.—Hygrometry in Paper Testing. *Paper Tr. J.*, **94** (2): 34-42, 1932.

2. Paper Testing Committee, Technical Section of the Papers Makers' Association of Great Britain and Ireland. First Report, 1937.

3. Skinner, S.—Dictionary of Applied Physics (Edited by Sir Richard Glazebrook), Vol. III., p. 426 (Macmillan & Co. Ltd., 1923).

RELATIVE HUMIDITY CHART FOR WET AND DRY BULB THERMOMETERS (BASED ON PERNTER'S FORMULA FOR AIR SPEEDS FROM 1 TO 1.5 M. PER SECOND).



Appendix.

The calculation of relative humidities as (a) the ratio of actual vapour pressure to saturated vapour pressure, and (b) the ratio of actual weight of vapour per gram of dry air to weight of vapour per gram of dry air when saturated.

Consider air at a dry bulb temperature of 21.1°C. (70°F.) and 65 per cent. relative humidity according to definition (*a*) which is the correct definition; barometric pressure 760 mm.

The saturated vapour pressure = 18.765 mm.

∴ pressure of air alone = 760 − 18.765 = 741.235.

At 65 per cent. relative humidity the vapour pressure = 18.765 × 0.65 = 12.197.

∴ pressure of air alone = 760 − 12.197 = 747.803.

If a saturated atmosphere containing 1 gram of dry air occupies V cc. its pressure being 741.235 mm., then the volume occupied by 1 gram of dry air at 65 per cent. relative humidity is—

$$\frac{V \times 741.235}{747.803} \text{ cc.}$$

If W grams of vapour at 100 per cent. saturation occupy V cc., or there are $\frac{W}{V}$ grams per cc., at 65 per cent. relative humidity there would be 0.65 $\frac{W}{V}$ grams per cc. Hence in the 1 gram of dry air there would be—

$$0.65\ \frac{W}{V} \times \frac{V \times 741.235}{747.803}$$ grams of vapour, or the relative humidity

expressed on the weight ratio is—

$$0.65\ \frac{W}{V} \times \frac{V \times 741.235}{747.803} \times \frac{1}{W}$$

$$= 0.644 = 64.4 \text{ per cent.}$$

Hence the error due to the latter method of expressing the relative humidity is, in this example, 0.6 per cent.

Tests on Small Clear Specimens of Red Tulip Oak (*Tarrietia argyrodendron var. peralata*).

*By R. S. T. Kingston, B.Sc., B.E.**

At the request of the Queensland Forest Service, the Division of Forest Products has carried out a systematic series of tests on six trees of red tulip oak to determine the mechanical and physical properties of this timber; this work has been carried out in co-operation with that Service. The detailed analysis of the results of the tests, which have been carried out generally in accordance with the A.S.T.M.(1) and B.S.I.(2) standard specifications, will be published in due course. In the meantime, it is considered advisable to publish the species means for the various properties.

The figures given are directly comparable with those previously published by officers of this Division for local and overseas species (3), and with results published by the Forest Products Laboratories of other English speaking countries. The figures apply only to specimens which are entirely free from defects and therefore can only be used in comparing the properties of clear wood or of material of equivalent strength grade.

In the case of toughness, compression perpendicular to the grain, and hardness, the words "radial" and "tangential" specify the face to which the load was applied, whilst in the case of shear and cleavage they specify the plane of fracture.

Average Mechanical Properties of Small Clear Specimens of Red Tulip Oak.

Property.	Moisture Condition.	Species Average.
Moisture Content, per cent.	Green ..	83
	Dry (at test)	13.4
Nominal Specific Gravity (weight oven-dry, volume at test)	Green ..	0.629
	12 per cent.	0.708
Weight per cubic foot, lb.	Green ..	72
	12 per cent.	49.5
Static Bending—		
Fibre stress at limit of proportionality, lb./sq. in. ..	Green ..	5,850
	12 per cent.	10,100
Modulus of Rupture, lb./sq. in.	Green ..	11,500
	12 per cent.	18,300
Modulus of Elasticity, 1,000 lb./sq. in.	Green ..	1,800
	12 per cent.	2,150
Work to limit of proportionality, in. lb./cu. in. ..	Green ..	1.1
	12 per cent.	2.7
Work to Maximum Load, in. lb./cu. in.	Green ..	11.6
	12 per cent.	18.6
Total Work, in. lb./cu. in.	Green ..	29.5
	12 per cent.	28.7

* An officer of the Division of Forest Products.

AVERAGE MECHANICAL PROPERTIES OF SMALL CLEAR SPECIMENS OF RED TULIP OAK—*continued.*

Property.	Moisture Condition.	Species Average.
Toughness—		
Radial, in. lb. ..	Green	222
	12 per cent.	161
Tangential, in. lb.	Green	214
	12 per cent.	166
Compression parallel to the Grain—		
Maximum Crushing Strength, lb./sq. in. ..	Green	5,360
	12 per cent.	8,900
Compression perpendicular to Grain, lb./sq. in.—		
(*a*) 2-in. x 2-in. x 6-in. specimen (A.S.T.M. Standard)—		
Fibre stress at limit of proportionality—		
Radial	Green	1,140
	12 per cent.	2,010
Tangential	Green	1,280
	12 per cent.	2,850
Stress at 1/10 inch deflection—		
Radial	Green	2,220
	12 per cent.	3,100
Tangential	Green	2,410
	12 per cent.	4,100
(*b*) 2-in. cube (B.S.I. Standard)—		
Fibre stress at limit of proportionality—		
Radial	Green	..
	12 per cent.	1,230
Tangential	Green	..
	12 per cent.	1,730
Stress at 1/10-in. deflection—		
Radial	Green	..
	12 per cent.	2,050
Tangential	Green	..
	12 per cent.	2,590
Hardness, lb.—		
Radial	Green	1,450
	12 per cent.	1,970
Tangential	Green	1,420
	12 per cent.	2,060
End ..	Green	1,410
	12 per cent.	2,370
Shear, lb./sq. in.—		
(*a*) Rebated Specimen (A.S.T.M. Standard)—		
Radial ..	Green	1,150
	12 per cent.	1,910
Tangential	Green	1,390
	12 per cent.	2,080
(*b*) 2-in. cube (B.S.I. Standard)—		
Radial ..	Green	..
	12 per cent.	2,180
Tangential	Green	..
	12 per cent.	2,150
Cleavage, lb./inch width—		
Radial	Green	325
	12 per cent.	465
Tangential	Green	475
	12 per cent.	590

References.

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3. Langlands, Ian.—The strength of Small Clear Specimens of Some Overseas Timbers. *J. Coun. Sci. Ind. Res.* (Aust.), **11**: 302, 1938.

The Estimation of Butterfat Losses in Churning.

*By W. J. Wiley, D.Sc.**

Summary.

The methods of calculating the fat losses in churning which have been proposed by Udy and by Bird and Derby are discussed. Both methods have been found to be reasonably accurate by comparing the results obtained by their use with the results obtained by measuring directly the quantity of fat in the buttermilk and wash water.

1. Introduction.

The only measure of manufacturing efficiency adopted by many butter factories is that of the "over-run"; the quantity of butter made in excess of the quantity of fat received. The accuracy of weighing and analysing the cream, the composition of the butter manufactured, and the amount of fat in the cream which is not turned into butter, all influence the "over-run." Thus the loss of "over-run" caused by inefficiency at one stage of manufacture may be counterbalanced by some other factor affecting the "over-run," and the inefficiency may not be detected. The buttermaker should be alert to detect and reduce when possible any actual loss of fat, even if the factory "over-run" is satisfactory.

The most important loss of fat occurs in the buttermilk, and this loss can not generally be measured directly because of the impracticability of weighing the buttermilk. It can, however, be estimated indirectly. The object of this paper is to describe the results of some experimental churnings in which the losses were measured directly by weighing and analysing the buttermilk and were also calculated by two indirect methods.

2. The Method of Udy.

This method (Udy (1)) has been used considerably in New Zealand. It is particularly suitable for checking the efficiency of churning in a factory over a day's run or in those cases where a central laboratory checks the manufacturing operations. The method corrects for the increased quantity of buttermilk caused by dilution of the cream by rinse water, neutralizer, and any "break water" which may be used. The calculation is based on (*a*) the percentage of fat in the cream as received at the factory, (*b*) the percentage of fat in the buttermilk, and the assumptions (*c*) that the cream serum as received at the factory contains 8.8 per cent. solids not fat, (*d*) that the "over-run" is 20 per cent., and (*e*) that the butter contains 10 per cent. of undiluted cream serum. McDowall (2) has discussed the method and has shown that moderate variations from these assumed figures do not seriously influence the results.

* An officer of the Council stationed at the Dairy College of Science and Technology, Werribee, Victoria, by courtesy of the Victorian Department of Agriculture.

$$\text{The percentage fat loss} = \frac{\begin{array}{c}\text{Weight of unwatered} \\ \text{buttermilk from 100} \\ \text{parts of cream}\end{array} \times \begin{array}{c}\text{Fat test of un-} \\ \text{watered} \\ \text{buttermilk}\end{array}}{\text{Fat test of cream as received.}}$$

The weight of unwatered buttermilk from 100 parts of cream is calculated thus:—100 parts of cream give $\frac{120}{100} \times$ (fat test of cream). parts of butter (assumption *d*). This butter contains 10 per cent. of unwatered buttermilk (assumption *e*), so the quantity of buttermilk retained in the butter is 0.12 $\times$ fat test of cream. The total quantity of buttermilk, i.e. serum in the cream, is 100 — fat test, and as the butter retains 0.12 $\times$ fat test, the quantity run away is 100 — (1.12 $\times$ fat test of cream).

The formula may thus be expressed:—

$$\text{(1) The percentage fat loss} = \frac{\text{100 — 1.12 Fat test of cream received}}{\text{Fat test of cream received.}} \times \begin{array}{c}\text{Fat test of} \\ \text{unwatered} \\ \text{buttermilk}\end{array}$$

A Table can readily be constructed giving values of the factor—

$$\frac{\text{Weight of unwatered buttermilk from 100 parts of cream}}{\text{Fat test of cream as received.}}$$

for the different fat tests of the cream likely to be received.

The buttermilk which is analysed is the watered buttermilk. The percentage of solids-not-fat in this is determined (most readily by calculation from the percentage of fat and a lactometer reading). The percentage of fat in this watered buttermilk is multiplied by $\frac{8.8}{\text{solids-not-fat}}$ (assumption *c*) in order to determine the fat test of the unwatered buttermilk.

3. The Method of Bird and Derby.

Bird and Derby (3) have used a method of calculation which is of particular value for experimental purposes. It is based on (*a*) the percentage of fat in the cream at the time of churning, (*b*) the percentage of fat in the buttermilk, and the assumption (*c*) that the composition of the butter granules is such that there is an over-run of 20 per cent. at the time of drawing the buttermilk.

The quantity of butter from 100 parts of cream = fat test of cream at churning $\times \frac{120}{100}$ (assumption *c*). The quantity of buttermilk

$= 100 —$ fat test of cream at churning $\times \frac{120}{100}$

$$\text{(2) The percentage fat loss} = \frac{\text{Buttermilk from 100 parts cream}}{\text{Fat test of cream at churning.}} \times \begin{array}{c}\text{Fat test of} \\ \text{buttermilk}\end{array}$$

$$= \frac{\text{100 — 1.2 fat test of cream}}{\text{Fat test of cream at churning.}} \times \begin{array}{c}\text{Fat test of} \\ \text{buttermilk}\end{array}$$

On comparing equations (1) and (2) it will be seen that they are not in general compatible. If no dilution of the cream or buttermilk occurred, both equations should be identical, but they differ by the factor used to multiply the fat test of the cream by, in order to calculate the proportion of buttermilk. If a 40 per cent. cream were churned, without dilution equation (1) would show a loss 0.08 per cent. higher than equation (2) for any given buttermilk test; the difference is not great.

The discrepancy arises from the different assumption used in estimating the proportion of buttermilk. Udy's assumption that butter contains 10 per cent. of unwatered buttermilk is based on the proportion of nitrogen found in commercial butters which have been churned from creams which have always been diluted to some extent. As it must be assumed that a constant proportion of cream serum is incorporated in the butter, the assumption of a constant proportion, 10 per cent., of unwatered buttermilk in the butter really implies a constant dilution of the cream at churning time.

If the assumption required for the methods of Udy and Bird and Derby applied exactly, the dilution of the cream at churning time for which both methods should give identical results can be calculated thus:—

Let F = fat test of cream at churning
F' = fat test of unwatered cream
f = fat test of buttermilk
f' = fat test of unwatered buttermilk
S = solids-not-fat.

$$\text{Then } F = \frac{S}{8.8} \times F'$$

$$\text{and } f = \frac{S}{8.8} \times f'$$

$$\text{By Bird's formula, loss} = \frac{(100 - 1.2\,F)}{F} \times f$$

$$= \frac{100 - 1.2\,\frac{S}{8.8}\,F'}{\frac{S}{8.8} \times F'} \times \frac{S}{8.8}\,f'$$

$$= \frac{100 - 1.2\,\frac{S}{8.8}\,F'}{F'} \times f'$$

$$\text{By Udy's formula, loss} = \frac{100 - 1.12\,F'}{F'} \times f'$$

If both formulae are to give the same result it is apparent that—

$$1.2\,\frac{S}{8.8} \times F' = 1.12\,F'$$

$$\text{and } \frac{S}{8.8} = \frac{1.12}{1.2} = 0.933$$

which is equivalent to 6.7 per cent. of added water.

Bird and Derby assume that the 20 per cent. over-run is composed entirely of cream serum, i.e., buttermilk. This implies that the butter contains 16.7 per cent. of buttermilk, and if the buttermilk contains 8 per cent. of solids-not-fat, that the butter contains 1.3 per cent. of "curd" and 15.4 per cent. of moisture. In practice the butter granules are always washed and the free buttermilk is displaced by wash water, but the moisture, when first determined, is rarely above about 15 per cent. With New Zealand methods of manufacture the assumption of a 20 per cent. over-run composed of buttermilk is undoubtedly somewhat high.

A comparison of the loss calculated by Udy's and Bird and Derby's methods for a large number of churnings shows that they generally give closely agreeing results, and the results given in this paper show them to be reasonably accurate, so that in practice any deviations from the composition of butter and cream assumed for the purposes of calculation, are not of importance. The method of Bird and Derby is simpler to apply and is based on less assumptions so may be preferable under some conditions. If it were desired to determine the losses over a full day's churning, it would be easy to make a composite sample of the creams at each churning and of the buttermilks from these churnings and, from the proportions of fat in these, calculate the loss by Bird and Derby's formula. It is essential, however, that no break water or wash water be included in the buttermilk sample, and if conditions do not permit of obtaining such a sample Udy's method of calculation must be used.

4. Experimental.

The butters were manufactured from sweet cream which had been pasteurized at 200°F. in a Murray Vacreator. The cream was cooled over a direct expansion cooler to churning temperature, about 45°F., and held at that temperature overnight. The butter granules were washed once with a quantity of water about equal to the quantity of cream churned. About 200 lb. of cream were churned in a 1,200-lb. churn. The churn was thus underfilled, and this fact, together with the churning temperature which was rather high for the nature of the cream (spring cream) being churned, made fat losses in the buttermilk particularly high. This was really an advantage, as it enabled a better comparison to be made of the accuracy of the different methods of estimation.

The proportion of fat in the cream was determined by the Babcock and Rose-Gottlieb methods. The results by both methods agreed closely. The fat in the buttermilk was determined by the butyl-alcohol and the Rose-Gottlieb methods, and good agreement obtained. The proportion of fat in the wash water was determined by taking a large sample, 200 ml., adding 30 ml. ammonia and 50 ml. of alcohol, and extracting with mixed ethers.

In order to be sure that the losses were correctly estimated, every stage of the manufacturing process was followed quantitatively. The details of one typical experimental churning were as follows:—

——	Weight, Lb.	Per Cent. Fat.	Weight of Fat, Lb.
Material entering churn—			
Cream	220·75	36·5	80·6
Wash water	259·75	..	..
Salt	1·5	..	..
Total	482·0	..	80·6
Material leaving churn—			
Butter	92·75	82·7	76·7
Butter-milk	113·5	2·4	2·7
Wash water	273·75	0·1	0·3
Total	480·0	..	79·7

There was thus a reasonably good agreement between the quantity of material entering the churn and the quantity recovered.

The percentage loss of fat in the buttermilk and wash water was—

$$\frac{2.7 + 0.3}{80.6} \times 100 = 3.7.$$

The percentage loss calculated by Bird and Derby's method was—

$$\frac{100 - 1.2 \times 36.5}{36.5} \times 2.4 = 3.7$$

The percentage loss by Udy's method was determined thus:—The lactometer reading of the buttermilk was 28.5. The percentage of solids-not-fat calculated by Richmond's formula (S.N.F. = 0.25 lactometer reading + 0.2 per cent. fat + 0.14) is 7.7. The percentage of fat in the "unwatered buttermilk" is $\frac{8.8}{7.7} \times 2.4 = 2.74$. The percentage of fat in the cream as received at the factory was 41. The percentage loss by Udy's formula is thus $\frac{100 - 1.12 \times 41}{41} \times 2.74 = 3.6$. The losses determined by (*a*) weighing and analysing the cream, buttermilk, and wash water, (*b*) Udy's method, and (*c*) Bird and Derby's method, for eleven experimental churnings are shown in Table 1.

TABLE 1.—PERCENTAGE FAT LOSSES DETERMINED BY DIFFERENT METHODS.

By Weighing.	Udy's Method.	Bird and Derby's Method.
3·85	3·8	3·75
3·9	3·65	3·6
3·45	3·4	3·1
3·35	3·15	3·05
3·7	3·7	3·6
3·9	3·65	3·95
3·85	3·65	3·9
4·1	3·9	4·2
4·55	4·4	4·4
5·0	4·8	5·1
4·2	4·1	4·1
Mean 3·99	3·84	3·89

It will be seen that in spite of the exceptionally high fat losses recorded in these experiments, the three methods give results which agree reasonably.

The losses for 100 other churnings were calculated to the first decimal place by Udy's and by Bird and Derby's methods. These churnings were made for various experimental purposes, and details such as methods of pasteurization, cooling of cream, churning temperatures, and quantity of cream churned, varied considerably. The fat losses ranged from 3.1 per cent. to 0.9 per cent. The mean loss calculated by Udy's method was 1.611 per cent. and by Bird and Derby's method 1.616 per cent. The distribution of differences was as shown in Table 2.

TABLE 2.—DISTRIBUTION OF DIFFERENCES IN FAT LOSSES CALCULATED BY TWO METHODS.

—	Udy's Method Higher.					Bird and Derby's Method Higher.			
Difference	0·4	0·3	0·2	0·1	0	0·1	0·2	0·3	0·4
Number of samples ..	1	2	4	16	47	23	6	0	1

There was no tendency for either method to give consistently higher results and 96 per cent. of the results agreed within 0.2 per cent.

It is concluded that the methods proposed by Udy and by Bird and Derby are reasonably accurate.

5. Acknowledgments.

The work described in this paper was done at the Dairy Research Institute (N.Z.). The author is grateful to Professor W. Riddet for granting factory and laboratory assistance, to Drs. F. H. McDowall and H. R. Whitehead for valuable criticism, and to the staff of the experimental butter factory for their ready co-operation in the work.

6. References.

1. Udy, W. H. (1929).—*N.Z. J. Sci. and Tech.*, **11**: 249.
2. McDowall, F. H. (1938).—*N.Z. J. Sci. and Tech.*, **19**: 682.
3. Bird, E. W., and Derby, H. A. (1937).—Iowa Ag. Expt. Stn. Res. Bull. 214.

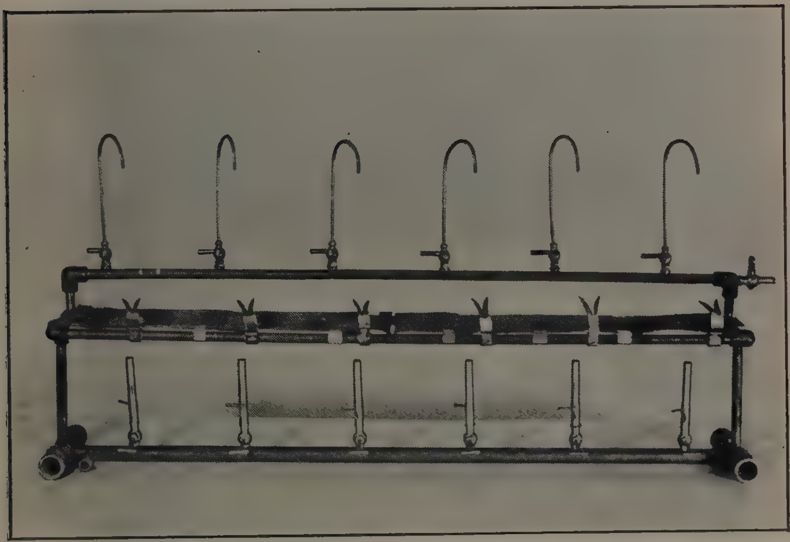
The Sexuality of *Ophiobolus graminis* Sacc.

By N. H. White, B.Sc.

Erratum.

An error occurred on page 211 of this article which appeared in the previous issue. In the second paragraph of section 5, the 17th line should have read " cultures was not greater than in single-spore cultures. Furthermore ".

The Internal Lacquering of Tinplate Containers for Foods.
(See page 303.)



Apparatus for tin determinations.

PLATE 2.

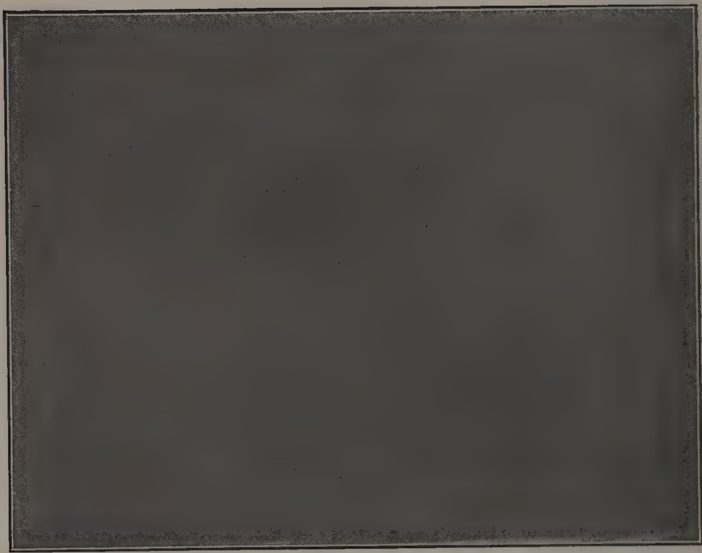


Fig. 1.—Inner surface of a plain can before use. (×2.5).

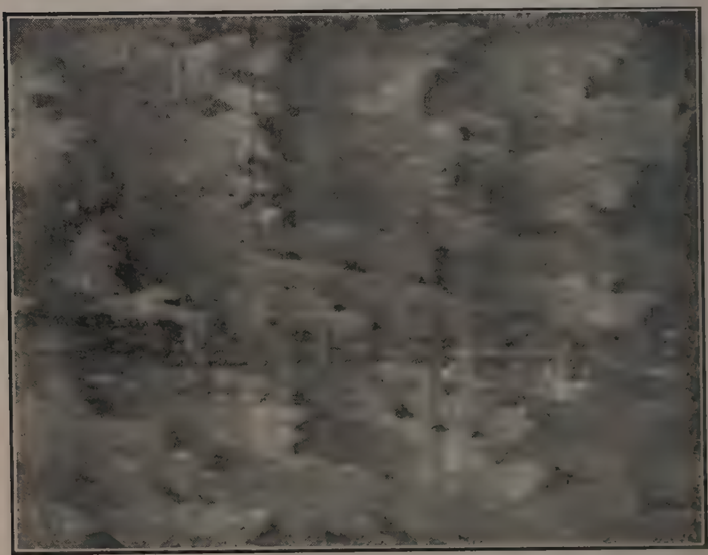


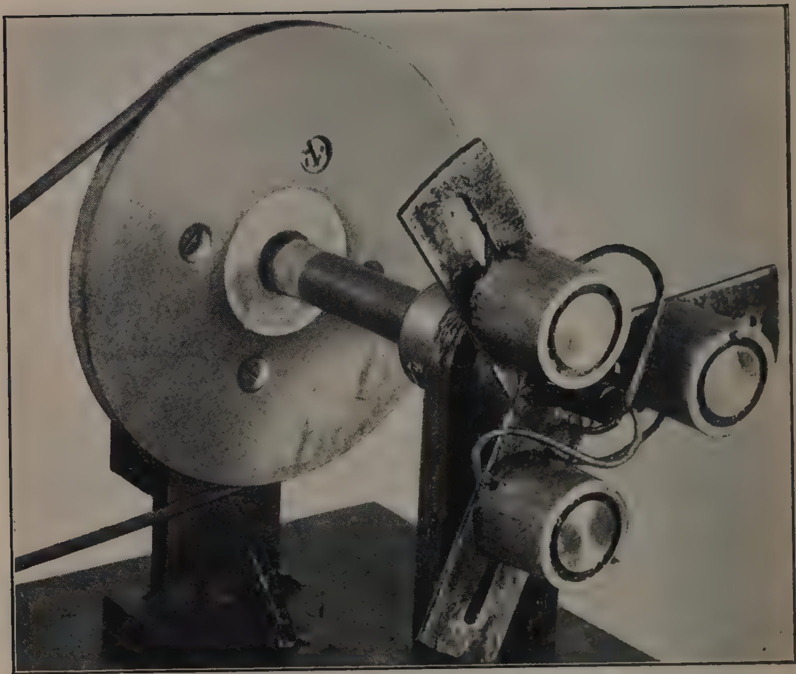
Fig. 2.—Inner surface of a plain can which contained orange juice for 26 weeks. (×2.5).

PLATE 3.

FIG. 1.—Inner surface of a can, spray-lacquered after making up, which contained orange juice for 26 weeks. ($\times 2.5$). The intact lacquer film presents a completely unrelieved surface.

FIG. 2—Inner surface of a can, lacquered in the plate, which contained orange juice for 26 weeks. ($\times 2.5$).

PLATE 4.



Electro-magnetic turntable for spray-lacquering cans.

NOTES.

The Use of Blue Raddle to prevent Blowfly Strike in Sheep.

This method was proposed in 1937 by Dr. George Watt of Wellington, New South Wales, who claimed that painting the breech of sheep with a special blue, either in raddle or fluid form, rendered them immune to blowfly attack. Striking instances of the apparent effectiveness of the method were reported from time to time by a number of pastoralists, with the result that the claim received wide publicity during the following year, though there was actually no scientific evidence to support the hypothesis that blue would repel blowflies or flies of any other species.

It was decided towards the end of 1938 that a number of tests should be carried out under strictly controlled conditions to establish definitely the efficiency or otherwise of the method. The Council for Scientific and Industrial Research was to undertake field and laboratory tests at "Gilruth Plains" National Field Station, Cunnamulla, and at the insectary, Canberra, while the New South Wales Department of Agriculture had decided to carry out tests at its Trangie Experimental Farm of a nature similar to those being undertaken at Cunnamulla by the Council.

At "Gilruth Plains," a flock of 319 B and C class four-tooth ewes, moderately to highly susceptible to blowfly strike, was divided into three identical groups. A supply of the prepared raddle was obtained and the three groups variously treated. In the first, the breech area was moistened with water and blue raddle rubbed in over the whole area; in the second, the breech area was moistened with a watery solution containing 2 oz. boro-glyceride (pharmaceutical) to the gallon, and the blue raddle rubbed in over the whole area, while the animals of the third group were left untreated and served as controls. The experimental sheep were turned out with the rest of the flock from which they had been selected, and all kept under close observation. No strikes occurred in any sheep on the property during the next 51 days, but fly activity then began, and during the following 56 days a number of strikes were recorded in the experimental groups.

In the experiments conducted by the New South Wales Department of Agriculture, three groups of 100 sheep were used. Each group consisted of approximately equal numbers of A, B, and C class sheep, and all were run together under identical conditions. In the first experiment, one group was treated with blue raddle, the second was swabbed with boro-glyceride, and the third was left untreated. Breech strikes occurring during the ensuing 41 days were noted. A second experiment was then undertaken, using the same sheep, after crutching and re-treating as in the first experiment, and the strikes during the following 53 days recorded.

The results of these small-scale field experiments conducted at "Gilruth Plains" and Trangie are summarized in the following table:—

Treatment	Number of Strikes
"GILRUTH PLAINS"	
Raddle and water	17
Raddle and boro-glyceride	21
Untreated controls	13

TRANGIE

	Uncrutched	Crutched
Treatment with blue	21	8
Swabbed with boro-glyceride	8	8
Untreated controls	16	9

Further experiments carried out in the insectary at Canberra failed to indicate that treated sheep were less susceptible to strike than untreated. Treated and untreated areas, made attractive by means of indole solution, each showed the same number of strikes after 6 hours' exposure to blowflies.

The results of these experiments, carried out independently by different workers, have shown that any repellent effect of the treatment is very transitory. As the blue treatment did not protect sheep under the conditions of the low strike incidence that prevailed during the period of the field experiments, the conclusion was reached that it is not likely to protect under less favorable conditions.

"Dairy Science Abstracts"—A New Journal.

Mention has already been made* of the Imperial Bureau of Dairy Science, which was recently established in England, at Shinfield, near Reading. The functions of the Bureau are, briefly, to collect and distribute information bearing on the different branches of dairy science, and to establish and maintain contact between research workers throughout the Empire. In this work, the quarterly publication of *Dairy Science Abstracts* will play an important part, and the initial number of the journal appeared in May of this year.

The journal aims at providing a record of current research work in all fields of dairy science, irrespective of the country in which it is carried out, or of the language in which it is published. Titles of articles are included with full details of place of original publication and, where considered necessary, abstracts written by dairy scientists. Special attention is paid to papers published in journals of limited distribution, and in less well-known languages. Presentation of the abstracts is similar to that in *Chemical Abstracts*; each number will contain an author index, and each annual volume will contain author and subject indexes.

* This *Journal* 12: 89. 1939.

The subscription is 25s. per volume of four numbers, post free (payable in advance), with a discount of 5s. to British subjects who send their subscriptions direct to the Bureau. (Prices are in sterling.)

The first issue consists of 113 pages, divided into eight main divisions and numerous subdivisions. In the section on husbandry, breeding and feeding for milk, recording, and the technique of milk production, are discussed; technology includes milk, cream, butter, cheese, dried products, ice-cream, disposal of wastes, buildings, and dairy engineering and equipment; bacteriology and mycology are concerned with milk production, processing, analysis, defects, animal diseases, and milk and public health. Other sections are on physiology, concerning both milk secretion and the value of milk products as food, economics, control and standards, chemistry and physics.

In short, the journal covers an extremely wide range of interests and will be of undoubted value to many connected with the dairying industry.

Star Grasses.

*Contributed by A. McTaggart, B.S.A., M.S.A., Ph.D.**

In view of the recent press publicity given to the discovery in East-Central Africa by a British Expedition of the so-called Giant Star grass, it may be of interest to the readers of this *Journal* to learn of the experience of the Council with star grass (*Cynodon plectostachyum*), of which the above-mentioned is believed to be a particularly vigorous form.

During the past decade, the Council's Division of Plant Industry introduced from Kenya, Uganda, Tanganyika, and the United States of America, seven grasses which bore the name of star grass (*Cynodon plectostachyum*). Six of these were believed to be representatives of the species. One in particular (C.P.I.† 3683), which was introduced in September, 1932, from Kenya, made such remarkably vigorous growth and spread so rapidly in the Plant Introduction Area at Lawes that fears were entertained by officers of the Council that, when once distributed, it might readily become troublesome in good rainfall sub-tropical and tropical cultivated areas. The Division of Plant Industry even went so far as to issue, in March, 1936, a warning with respect to it. Though the grass is productive, palatable, drought-resisting to a degree, and suitable for controlling soil erosion in districts favouring its growth, the view is still held by the Division that, without the constant use of proper control measures, it could readily become a plant pest in areas of good rainfall, and particularly where cultivation is practised and frosts are negligible.

The particularly vigorous type mentioned above had characteristics resembling these of the so-called giant star grass, as, for example, the remarkable rapidity of lateral growth or spread, and for this reason one

* An officer of the Council's Division of Plant Industry.

† C.P.I. = Commonwealth Plant Introduction.

is inclined to believe that, if C.P.I. 3683 is not actually identical with the latter grass, it resembles it very closely in its unusual vigour and aggressiveness. Indeed, the name "Giant Star" might fittingly be applied to the introduction from Kenya. The fact that it came from Nairobi (Kenya), where the outstandingly vigorous type now grown in South Africa originated, lends support to the possibility of identical origin.

Cynodon plectostachyum (C.P.I. 3683) is a semi-decumbent grass with numerous fine, lanceolate leaves and long trailing purplish stems that root at the nodes. Its foliage is rather dense and very spreading, and at maturity attains a height of 2½ to 3½ feet. The leaves, borne in pairs and opposite each other, are slightly pubescent (short-haired), the leaf sheaths being distinctly so.

As suggested above, star grass (*Cynodon plectostachyum*) is readily injured by frost, and the claim has been made that it is held in check in frost-prevalent districts. This indicates that the grass is naturally adapted to a sub-tropical or tropical climate where frost is either unknown or occurs only slightly. It also indicates that the grass can be grown without danger of spreading even on agricultural land in regions of favorable rainfall where frosts are sufficiently intense to check the growth, but not so severe as to exterminate the plant when once established.

Pastoral Research—Grants by the Australian Wool Board.

Reference has been made in past issues of this *Journal* (**10**: 173, 1937, and **11**: 350, 1938) to the contributions made by the Australian Wool Board towards the pastoral research work being carried out by the Council. The initial contribution of £17,500 by the Board, together with the generosity of the Queensland State Government, were directly responsible for the establishment of the National Field Station, "Gilruth Plains," at Cunnamulla, Queensland, while later grants enabled the animal health investigations of the Council to be extended to new problems in a few cases, and to be intensified in others. The earlier grants led to the intensification of investigations into problems relative to the sheep blowfly, toxaemic jaundice and foot-rot in sheep, sheep parasitology, genetics, and fertility, while further grants made from time to time have provided financial assistance which is of very material benefit in enabling the Council to further its investigations both on nutrition in relation to wool production and on agrostological problems.

At a meeting of the Australian Wool Board held recently, it was resolved to renew grants made available to the Council last year, and amounting to the sum of £7,400. These grants are in addition to those made annually since 1937 towards a number of other investigations. The work thus supported is now well advanced. Progress is being made in the study of grains and other food substances which can be used for feeding sheep during the prevalence of drought. Much valuable information is being obtained relative to fertility in sheep, to methods of improving the amount and quality of wool, and to the chemical and physical properties of the wool fibre bearing on its extended utilization.

An intensive study is being made of individual pasture plants, particularly in relation to the grazing animal. Work is in progress on the development of improved pastures in the moderate to low rainfall areas.

Considerable increases in the appropriate technical staffs of the Council, in addition to extensions and improvements to laboratory accommodation and equipment, have resulted directly from grants by the Australian Wool Board, whose generosity has allowed of an expenditure to the end of the financial year 1938-39 of over £31,000 in connexion with the Council's investigation of animal health and allied problems.

Posidonia Fibre.

At the June, 1939, meeting of the Australian Agricultural Council, it was resolved that the production and processing of fibres in Australia —particularly marine fibres—should be thoroughly explored. Reference to marine fibres was prompted by the existence of large deposits of a seaweed-like growth along the South Australian coast. Various attempts have been made in the past to utilize these deposits, and, as a result, indications of various directions in which the material might be used in times of emergency as a substitute for imported products have been obtained. The Council has decided not to carry out any experiments with the material at the present juncture (it is, however, intensifying its work on other fibres), but the following information concerning the fibre will be of interest.

Marine fibre is the fibrous portion of the leaf sheath of the sea plant, *Posidonia Australis*, which grows abundantly in the shallow waters around the coast of South Australia. The plant is a perennial growth, and flowers and seeds every year. As it dies, the fleshy parts are retted out, assisted by the mechanical action of the sand, and a small residue of relatively indestructible fibre is left. This fibre resembles jute in many respects, but has several unique properties. Compared with other cellulose fibres, it is said to be remarkably resistant to rot and chemical action, and is comparatively non-inflammable, commencing to char only at a temperature of 350° F. It carbonizes at 428° F., and combustion sets in at 500° F.

Its thermal conductivity is only slightly greater than that of wool The principal defect of the fibre in its natural condition is its extreme brittleness. A considerable amount of work has been done with a view to correcting this defect. Treatment with a 1 per cent. solution of mineral acid—for example, sulphuric—has been found to give a substantial improvement, the treated fibre being sufficiently flexible to be knotted without breaking*. Later investigators have claimed further progress.

The deposits have been worked from time to time for a number of years, and over £200,000 has been expended in machinery and on plant development. Since 1938, a further attempt has been made to revive

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* Bulletin No. 14, Commonwealth Inst. Sc. & Ind., 1919, John Read and H. G. Smith.

the industry. It is estimated that the known workable deposits in South Australia would yield a total of approximately 4,600,000 tons of air-dried fibre. These deposits have been accumulating over a long period, but the plant is still growing abundantly, and some replenishment of the deposits may, therefore, be expected. The physical and chemical properties of the fibre have been studied by the Imperial Institute, the Department of Chemistry of South Australia*, and the former Commonwealth Institute of Science and Industry†. The investigations of the Commonwealth Institute extended over a period of some two years.

The costs of production were analysed by Mr. D. C. Winterbottom*. His figures are based on a study of actual operations covering a fairly substantial output, and were prepared in 1917. He arrived at a production cost at the works of £12 5s. 3d. per ton. It would thus seem that, even under present day conditions, it would be possible to place the material on the market at some figure under £20 per ton.

The fibre has been used in conjunction with low-grade wool and shoddy for the manufacture of lower quality materials. These developments took place prior to the war, and it is probable that subsequent developments in synthetic fibres will render this application less attractive.

The fibre is rather shorter in the staple than jute, which, in other aspects, it resembles. It has been carded into a yarn suitable for use in carpet manufacture and for the backing of oilcloths, linoleums, &c. The jute imports into the Commonwealth for 1937-38 amounted in value to £46,406, at a price of approximately £22 per ton. In addition, woolpacks to the value of £280,722 were imported. It is stated that, unlike jute, Posidonia reacts to acid dyes, and for this reason one of the major difficulties associated with the jute woolpack might be avoided.

The material has been successfully used for upholstery and for mattress making. The authorities of the Prince Alfred Hospital, Sydney, have used it in mattresses in place of horsehair. They reported very favourably on it, and stated that it stands up well to sterilization. The possibility of substituting this material for part of the Commonwealth's imports of kapok should be worth investigation; such imports for 1937-38 amounted in value to £226,477, at a price of approximately £60 per ton.

The material has given satisfactory results both for steam and refrigeration insulation. As an insulator for steam pipes it has been found superior to asbestos, which is commonly used for this purpose. For insulation of refrigerators it has been found equal to cork and superior to mineral wool. Imports of granulated cork and pressed cork-board total £64,237 for 1937-38. Values cannot be definitely arrived at, but would in all cases be substantially in excess of the cost of Posidonia fibre.

The fibre has been studied from the point of view of paper-making, but there appears to be no prospect of economic development for this purpose.

* Bulletin No. 4, South Australian Dept. Chem. 1917, D. C. Winterbottom.

† Bulletin No. 14, Commonwealth Inst. Sc. & Ind., 1919, John Read and H. G. Smith.

Scientific and Technical Information in Italy—A New Service.

In a previous issue of this *Journal* (**11**: 280, 1938), some details of the Council's formation of a new technical and research information section were given. It is of interest to note the recent establishment of a similar organization in Italy. In January, 1938, the "Centro Nazionale di Documentazione Tecnica" (National Centre for Technical Documentation) was formed as a branch of the Italian Council of Research (which is charged with similar functions to the Council for Scientific and Industrial Research in Australia).

The functions of the new Information Centre are:—

(i) To supply researchers, manufacturers, and any one requiring it, with documentary material in the fields of engineering and industry.

(ii) To publish an "International Bibliography of Engineering and Industry," i.e., a periodical survey of international literature concerning both those fields.

The following is an extract (translated) of a statement issued by Marshal Badoglio from the headquarters of the National Council in Rome:—

"After a preparatory stage, the new Institute has recently begun to work, and is in a position to supply bibliographical information, as well as information about patents. It is also enabled through its connections with specialists and with the chief centres of general and special documentation both in Italy and abroad, to act as a centre of information of a wider character; moreover, it can supply, on request, copies of papers either in their original language or in translation into Italian as well as other languages.

The first issue is now appearing of the 'International Bibliography of Engineering and Industry' for the months of January and February, 1938. The Institute is taking steps to bring the publication up to date so that it may possess that freshness of information which will form one of its chief merits.

The Bibliography will cover all branches of engineering and industry. However, in the present issue the two sections relating to electrical engineering and the technologies are wanting, as they are still in preparation. These gaps will be filled in process of time.

The creation of the new Institute is calculated to be a powerful help to both researchers and manufacturers. Of course, such a vast, complex, and delicate organism could not be born perfect or approaching perfection; time and practice will improve its organization, widen its scope, and better its output."

Recent Publications of the Council.

Since the last issue of this *Journal*, the following publication of the Council has been issued:—

Pamphlet No. 91.—"The Effect of Spacing and Time of Sowing on Yield and Yield Components of Wheat Varieties," by H. Fairfield Smith, B.Sc.(Agr.), M.S.A.

Various workers in the field of plant genetics have repeatedly stressed the necessity for investigating the effect of spacing between plants as a preliminary to devising a suitable technique for further investigation of the problem centring around yield in plant breeding. The Pamphlet discusses some experiments on this problem which were carried out at Canberra.

It was found that when seed is sown at the same rate per unit area, an increase of spacing between rows beyond 8 inches tends to decrease the yield of grain in its components, but does not appreciably alter the relative values of the ten varieties investigated.

Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

Bulletin No. 130.—"The Fleece of Sheep—A Review of Present Knowledge and an effort towards the establishment of Standard Methods in Fleece Chemistry," by Martin R. Freney, B.Sc.

Bulletin No. ?.—"The Wood Anatomy of Some Australian Lauraceae with Methods for Their Identification," by H. E. Dadswell, M.Sc., A.A.C.I., and Audrey M. Eckersley, M.Sc.

Pamphlet No. 92.—"The Density of Australian Timbers, Part II., Air-dry and Basic Density Data for 172 Timbers," by W. L. Greenhill, M.E., Dip.Sc., and H. E. Dadswell, M.Sc., A.A.C.I.

Pamphlet No. ?.—"Studies on the Marketing of Fresh Fish in Eastern Australia, Part I., Field Observations and Quantitative Bacterial Results," by E. J. Ferguson Wood, M.Sc., B.A.

Pamphlet No. ?.—"A Copper Deficiency in Plants in South Australia," by D. S. Riceman, B.Agr.Sc., C. M. Donald, B.Sc.Agr., and S. T. Evans, B.Sc.

Miscellaneous.—"Handbook of Structural Timber Design," prepared by the Division of Forest Products. This handbook gives the necessary information, formulae, design data, &c., for the design of timber structures; tables showing the load-carrying capacities of timber beams and columns are included.

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